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Impacts of red imported fire ants (Solenopsis invicta Buren) on native faunal communities in two pine-dominated forests

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IMPACTS OF RED IMPORTED FIRE ANTS (*SOLENOPSIS IVICTA* BUREN) ON NATIVE FAUNAL COMMUNITIES IN TWO PINE-DOMINATED FORESTS

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Abstract

Impacts red imported fire ants (RIFA) exert on native faunal communities were monitored in two pine-dominated ecosystems in Louisiana. After suppression of established RIFA populations with Amdro®, cotton mice (*Peromyscus gossypinus*), herpetofaunal, ground-dwelling invertebrate, Lycosidae, and non-target ant communities were compared between untreated-control and treated plots with respect to possible ecological impacts of RIFA on these communities. Efficacy of Amdro® (A. I. 0.7% hydramethylnon) was tested at Alexander State Forest and Sandy Hollow WMA, and was found to be effective at both sites for 99-42.3% and 97-48%, respectively, suppression of RIFA on treated plots, for three to seven months, with treatments administered in the evening at a rate 1.68 kg/ha. Following suppression, RIFA were shown to minimally impact cotton mice, ground-dwelling invertebrate populations, and Lycosidae species, indicating that RIFA is not the regulating factor in these communities. In the case of cotton mice, habitat conditions that favor cotton mice may also favor RIFA. The majority of non-target ants analyzed at Alexander State Forest and Sandy Hollow WMA also seem to coexist with RIFA, although some species including *Aphaenogaster rudis-texana*, *Crematogaster lineolata*, *Brachymrymex musculus*, *Paratrechina faisonensis*, *Pheidole dentata*, and *Pheidole metallescens* may occur in sparse, small populations in the presence of RIFA. At Alexander State Forest, both *Brachymrymex musculus* and *Tapinoma sessile* showed a positive response to RIFA suppression, indicating signs of competitive release. At Sandy Hollow WMA *Monomorium minimum* and *Prenolepis imparis* responded negatively to treatment, indicating that Amdro® may exhibit non-target effects to these two species. Herpetofaunal communities, particularly ground skink and southeastern five-lined skink populations may be negatively impacted by RIFA. However sample sizes for all herpetofauna species were low. Amdro® is

effective at suppressing RIFA populations in forested ecosystems; however the impacts RIFA pose on native ground-dwelling faunal communities may be minimal in these two pine-dominated communities.

Chapter 1.

Introduction

The red imported fire ant (RIFA), *Solenopsis invicta* Buren, was introduced to the Port of Mobile, Alabama, in the 1930's from South America (Buren 1972). The ant's native home range is the headwaters of the Paraguay River, located in northern Argentina and southern Brazil - a broad flood plain and wetlands known as the Pantanal (Vinson and Sorensen 1986). Urbanization in the United States has facilitated expansion of RIFA populations, which thrive in disturbed habitats (deShazo 1999). Aided by development of multiple queen colonies (polygyny), RIFA have spread from Mobile, AL via mating flights, colony fission, floating colonies on water, and by human-mediated transport. Such dispersal methods have allowed this species to expand to cover more than 308 million acres (Williams et al. 2001, Williams et al. 1999) in Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North and South Carolina, Oklahoma, Tennessee, Texas, and Puerto Rico (Callcott and Collins 1996). More recently Williams et al. (2001), Davis et al. (2001), and Korzukhin et al. (2001) have documented invasions of fire ants into New Mexico, Arizona, California, the West Indies, Australia, and New Zealand. Appendix A shows a map of the present range and possible future RIFA expansion in the United States as presented by Korzukhin et al. (2001).

Due to RIFA's high reproductive capacity, aggressive foraging behavior, and lack of natural enemies, these ants are often the dominant ant species in infested areas (Allen et al. 2004). A colony of RIFA can mature to hundreds-of-thousands of workers within a year. One-fifth of those individuals at any one time, through the life of a colony, are foragers (Taber 2000). RIFA are omnivorous, generalist foragers that feed on almost any type of animal or plant material (Vinson and Sorenson 1986). Arthropods, though, are the main portion of their diet; and armed with a paralyzing stinger, RIFA can locate and sting prey so that it can be consumed at leisure (Vinson and Sorenson 1986). RIFA's diet generally consists of arthropods, but larger prey are also consumed. A RIFA forager will recruit additional foragers from the colony if a prey item is too large for a single individual (Taber 2000). Following a chemical trail laid down by the single forager, hundreds of foragers will return to the large prey item and a chain-reaction massive sting response by all the foragers will subdue larger prey (Vinson and Sorenson 1986). RIFA are a serious nuisance to humans. They disrupt arthropod communities and negatively affect mammals, birds, and herpetofauna (Vinson 1997, Porter and Savignano 1990, Allen et al. 2004).

The taxonomic classification of RIFA has led to confusion in scientific literature, so a brief history is presented here for clarification. Not all *Solenopsis* species are considered fire ants; true fire ants comprise a collection of eighteen to twenty species native to the New World (Trager 1991). Presently, there are six true fire ant species in the United States: the red imported fire ant, *Solenopsis invicta* (RIFA); the black imported fire ant, *Solenopsis richteri* Forel (BIFA); the tropical fire ant, *Solenopsis geminata* Fabricius (TFA); the southern fire ant, *Solenopsis xyloni* McCook (SFA); the desert or golden fire ant, *Solenopsis aurea* Wheeler (GFA); and *Solenopsis amblychila*, an almost ignored species with no common name (Taber 2000). *Solenopsis amblychila*, SFA, and GFA are considered to be natives of the Unitied States where as RIFA, BIFA, and most likely TFA are all introduced species (Taber 2000).

BIFA were first documented in the United States by Henry Peter Loding in 1929. Loding (1929) named the species *Solenopsis saevissima richteri*, a variation or subspecies of a valid South American species, *Solenopsis saevissima* (Collins 1992). BIFA populations are now in danger of extirpation from the United States due to attack from humans, from its close relative

(RIFA), and from a hybrid of the two species *Solenopsis invicta X richteri* (Taber 2000). BIFA is credited by some as paving the way for success of RIFA; that is, BIFA may have dealt the first blow to native ant populations in southeastern United States (Lofgren et al. 1975, Jemal and Hugh-Jones 1993). Most likely, both BIFA and RIFA arrived in Mobile, Alabama by accident from South America and both were introduced by means of ships, though each species might have arrived on more than one occasion (Taber 2000).

Both RIFA and BIFA were originally considered subspecies of *Solenopsis saevissima*, which is now known to be a separate species that only occurs in South America (Taber 2000). Originally, the proposed name for RIFA was *Solenopsis saevissima wagneri*, named by F. Santschi in 1916 (Shattuck et al. 1999). Nearly half a century later W.F. Buren (1972), unaware of *Solenopsis saevissima wagneri*, named RIFA *Solenopsis invicta*. Due to rules of priority, *S. wagneri* should be the accepted scientific name for RIFA; but by the time Bolton (1995) published this correction, *S. invicta* had been used so extensively in scientific and popular literature that changing RIFA to *S. wagneri* would cause more confusion than benefit (Shattuck et al. 1999). Shattuck et al. (1999) proposed the conservation of *Solenopsis invicta* due to its common use in literature, and it is the official name.

The objectives of this study were to determine the efficacy of Amdro® for long-term and large-scale management of RIFA populations and monitor the impacts of RIFA suppression on small mammal, herpetofaunal, and invertebrate communities. Impacts of RIFA on wolf spiders (Lycosidae) and non-target ant species were also assessed throughout this study. The continuation of this project added two additional years of data to a Master's thesis begun by Keri E. Landry in 2002 and completed in spring 2004. A total of four years of data is compiled, analyzed and assessed to help better understand the possible effects RIFA have on native faunal communities.

Chapter 2.

Efficacy of Amdro® in Suppression of Red Imported Fire Ants in Longleaf-pine and Pine-hardwood Forests

Introduction

In 1929, Loding reported the presence of imported fire ants (IFA) in the United States (Loding 1929). Less than 10 years later the first organized control program began (Collins 1992). This began the epic battle of man versus ant.

This first control program was initiated in February 1937 in Baldwin County, Alabama, and four Federal, State, and County agencies cooperated. Cyanogas® Dust (48% calcium cyanide) was applied nest by nest by digging up each mound, applying the dust then covering each nest with soil. Approximately 809 hectares (2,000 acres) of vegetable cropland was treated (Eden and Arant 1949).

In 1947, the Mississippi State Plant Board began an IFA research program and by 1948 had appropriated $15,000 to fight fire ants with chlordane dust (Wilson and Eads 1949). In 1949, a cooperative project was conducted by Alabama, Mississippi, Florida, and the U. S. Department of Agriculture (USDA) to research biology, control, distribution, and economic importance of these invasive ants (Collins 1992). The Louisiana Legislature, in 1952, appropriated funds to provide farmers with chlordane at cost (Collins 1992). Arkansas followed suit in 1957 when the State Plant Board treated 4856.23 hectares (12,000 acres) by aircraft, applying heptachlor at 2.24 kg/ha (2 lb/acre, Anonymous 1958).

In 1957, concerns about the rate at which RIFA was expanding its range led U.S. Congress to provide $2.4 million dollars (matched by state agencies) and to authorize the USDA to begin a cooperative federal-state control/eradication program (Collins 1992). Between 1957 and 1959, 1,011,714 hectares (2.5 million acres) were treated with granular dieldrin or heptachlor (Brown 1961). Both insecticides were applied at 2.24 kg/ha (2 lb/acre), but in 1959 the rate of application was decreased to 0.28 kg/ha (0.25 lb/acre) with treatments spaced three to six months apart due to growing concerns for non-target impacts on wildlife and chemical residue problems (Collins 1992). At the same time, W. F. Barthel and C. S. Lofgren were chosen to organize a USDA Methods Development Laboratory in Gulfport, Mississippi to reduce the amount of residual insecticide needed to achieve control and secondly, to develop a toxic bait (Lofgren 1986). During 1960, the Federal Department of Agriculture (FDA) reduced the tolerance level of heptachlor on harvested crops to zero (Canter 1981). This change immediately made the control of RIFA impractical (Lofgren 1986).

Research from the Methods Development Laboratory in 1961 led to formulation of Mirex® granular bait (Lofgren et al. 1963). In 1963, the application rate was standardized at 2.8 kg/ha (2.5 lb/ac), but in 1965 was reduced to 1.4 kg/ha (0.57 lb/ac, Lofgren 1986). Mirex® was used extensively from 1967 to 1975 with approximately 45,281,380 ha (111,892,726.78 acres) treated until its registration was discontinued in 1977 by the Environmental Protection Agency (EPA) due to residues showing up in non-target organisms and its slow biodegradation (Lofgren 1986). Mirex® was taken off the market in 1977; from the late seventies into the early 1980's the USDA expanded its research program to focus on toxicants, insect growth regulators, pheromones, biocontrol, biology, ecology, and economics (Lofgren 1986).

The 1980's was a decade of bait production; beginning in August 1980, the EPA, after testing more than 5,000 compounds, registered American Cyanamid AC-217,300 (hydramethylnon) which was later formulated into a granular bait under the trade name Amdro® (Collins 1992, Vander Meer et al. 1982). Amdro®, active ingredient (A.I.) hydramethylnon is presently registered for use on pasture land, range grass, lawns, turf, and other nonagricultural land including plant nurseries (Collins 1992). Individual mound treatments or broadcast application by either ground or aerial dispersal systems are acceptable methods for dispersion of the bait (Collins 1992). Prodone® (A.I. Stauffer MV-678) was registered by the EPA on February 22, 1983, but is no longer marketed (Collins 1992). Affirm® (A.I. avermectin B_1a) was registered April 18, 1986, and the bait is currently marketed as Black Flag® Fire Ant Ender and as PT® 30 Ascend Fire Ant Bait using the same active ingredient (Collins 1992). Ascend® and Fire Ant Ender® are both registered for use on turf, lawns, and other noncrop areas (Collins 1992). Logic® (A.I. fenoxycarb) received registration in October 1985 and is also registered as Award® (Collins 1992). Award® and Logic® are registered for nonagricultural land such as lawns and ballparks (Collins 1992).

Efficacy and photodegradation of Amdro® has been tested by many researchers since its acceptance as a fire ant bait in 1980. Vander Meer et al. (1982) exposed Amdro® to natural summer climatic conditions in Florida and found rapid decomposition of hydramethylnon during daylight hours, due to photolysis, and no decomposition during evening hours. They also showed that this bait would not affect nontarget ant species and that it is ineffective for RIFA control after 12-30h exposure to sunlight, which makes Amdro® an environmentally friendly bait (Vander Meer et al. 1982). These results have also been confirmed by Apperson et al. (1984), who found that after 24 h the toxicant was barely detectable and undetectable after 48h. Manley (1982) conducted individual mound treatments using Amdro® with a series of 1-5 tablespoons per treatment; he found no significant difference in efficacy of the treatment rates with a range of 65-73% colony mortality. In a study testing efficacy of Amdro® on RIFA, broadcast bait application was shown to be more effective than individual mound treatments (Apperson et al.

1984). In most cases broadcast application of baits is usually the most cost-effective as well, and normally kills 85-95% of the colonies in treated areas (Collins 1992).

RIFA are also highly attracted to fats and oils, which granular baits use as a carrier for the toxicant (Horton et al. 1975). Amdro® suppresses RIFA within a month of treatment, but RIFA have been shown to resurge to pretreatment levels in three months after treatment; so multiple applications are necessary (Apperson et al. 1984). In some cases, Amdro® has been shown to keep RIFA colonies suppressed for up to 44 weeks on small-scale plots (0.2 ha or 0.5 acre, Lofgren and Williams 1985, Collins et al. 1992).

In the United States no one talks about eradicating fire ants anymore; the emphasis has shifted to controlling them at sites where they are a pest (Killion and Vinson 1995). RIFA escaped natural biological control when they invaded the United States; they occur in higher densities, in larger mounds, and constitute a larger fraction of the local ant community than they do in their native home range in South America (Porter et al. 1992).

To assess the efficacy of Amdro® on RIFA populations, broadcast applications of this granular bait were used within two pine-dominated landscapes, in Louisiana. RIFA numbers were monitored and compared between untreated-control and treated plots in respect to the efficacy of the Amdro® treatment.

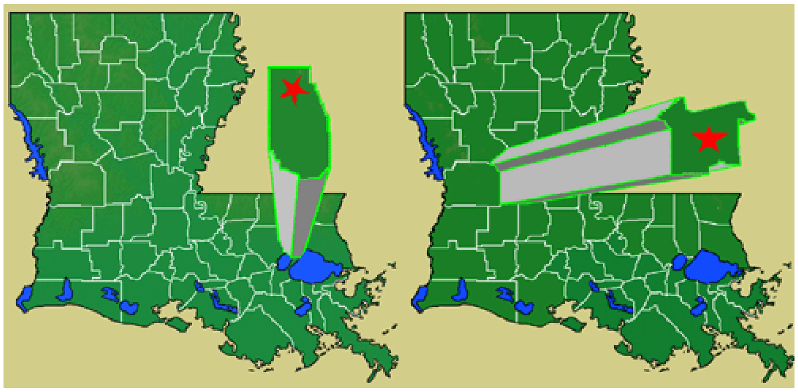
Methods

The experimental design for the study followed Landry (2004). Small mammal, herpetofauna, insect (discussed in chapters 3, 4, 5, respectively), and ant sampling occurred simultaneously on six 2.02 ha (5.0 acre) plots within each of two landscapes for four consecutive years. Four years of ant data were acquired by combining 2004 and 2005 sampling data with one year each of pre- and post-treatment data (2002 and 2003) obtained from Landry (2004). The pre-treatment year (2002) from here forward will be referred to as “period A” and post-treatment sampling period (2003, 2004, and 2005) referred to as “period B.” Comparisons were not made between landscapes but rather among treated and untreated-control plots within landscapes, because landscapes were not replicated. Experimental design consists of six, 2.02 ha plots with three replicates within each landscape. Treatment plots were randomly assigned in 2002 and remained the same throughout the experiment (Landry 2004).

Study Area

The study was conducted at Sandy Hollow Wildlife Management Area (WMA) in Tangipahoa Parish and Alexander State Forest WMA in Rapides Parish (Figure 2.1). Sandy Hollow is located approximately 16 km (10 miles) northeast of Amite, Louisiana on State Highway 10 (N 31º 6′ 49′′ , W -92º 30′ 41′′). The area comprises 1422.5 ha (3515 acres) which is owned by Louisiana Department of Wildlife and Fisheries. Most of this WMA is young longleaf pine (*Pinus palustris* Miller) with only a small portion of mature trees. The area is actively managed for upland game birds, mainly Northern Bobwhite Quail, *Colinus virginianus* (Linnaeus), and Mourning Dove, *Zenaida macroura* (Linnaeus). Prescribed burns are also administered on the area, which maintains a semi-open understory.

Alexander State Forest is located 16 km (10 miles) south of Alexandria, Louisiana and one mile east of Woodworth, Louisiana near U.S. Highway 167 (N 30º 48′ 15′′ , W -90º 25′ 4′′, Figure 2.1). The area consists of 3301.43 ha (8158 acres), including a 1052.18 ha (2600 acres) reservoir and is owned by the Louisiana Department of Natural Resources, Office of Forestry. The overstory consists mainly of managed loblolly pines (*Pinus taeda* Linnaeus) with scattered stands of longleaf and slash pines (*P. elliottii* Engelm). In addition, numerous species of hardwoods are widely scattered throughout the forest.



Figures 2.1. Locations of Sandy Hollow Wildlife Management Area in Tangipahoa Parish (left) and Alexander State Forest in Rapides Parish (right) in Louisiana (Pictures from LDWF website 2006).

Red Imported Fire Ant Control

Amdro® (A.I. 0.7% hydramethylnon) was broadcast over three randomly-assigned, treatment plots at each of two forests to suppress fire ants. Scotts Handy Green II® broadcast spreaders were used to apply Amdro® at a rate of 1.68 kg/ha (1.5 lb/acre) by hand (Figure 2.2). A pair of individuals stood arm-length apart and walked the entire area of each plot during treatment to ensure an even application of granular bait. RIFA control was previously administered in April, August, and October of 2003 by Keri Landry at both field sites. Treatments commenced in May 2004 and followed in June 2004, May 2005, and September 2005 at Sandy Hollow WMA. At Alexander State Forest treatments were conducted in May 2004 and May 2005.

Ant Sampling

Ant sampling consisted of two periods; sampling period A in which all samples were collected from untreated-control and treated plots prior to application of Amdro® and sampling period B where all samples were collected post-treatment. At Alexander State Forest period A samples were collected in February, June, September, and October 2002 as well as January and March 2003. Period B samples were administered in April, June, August, October, and

Figure 2.2. From left to right: Amdro® container Handy Green II® Spreader, and granular bait.

December 2003; March, April, June, August, and October 2004; and January, March, April, May, July, October, and December 2005. Sandy Hollow WMA period A samples were collected in January, April, June, September, and December 2002 as well as February 2003. Period B samples were collected in April, May, August, October, and December 2003; February, April, June, July, August, October, and December 2004; and March, April, May, July, October, and December 2005. Ant species numbers were measured using food traps that consisted of a 20-ml scintillation vial baited with 4 g Vienna sausage. Each vial was labeled and wrapped with aluminum foil to avoid ants vacating vials due to extreme heat. Sampling occurred before 1100 hours when ants are most active. Ten open vials were placed 18 m apart, on the ground in a diagonal transect across each 2.02 ha plot. After one hour the traps were collected and capped. The one-hour time span allowed ants to begin foraging but did not allow them to consume all the bait (Landry 2004). In the lab, the ants were frozen, thawed to count, then preserved and identified to species. Figure 2.3 shows the ant vials used to collect ant specimens.

Figure 2.3. Ant vials (from left to right) aluminum foil cover, Vienna sausage bait with label information, and frozen ants ready to be counted.

Statistical Analysis

SAS version 9.1 software package was used to assess the efficacy of Amdro® granular bait at suppressing RIFA on treated plots in two pine-dominated ecosystems in Louisiana (SAS Institute Inc. 2002). Proc Mixed was used within SAS to detect significant differences in mean RIFA numbers between untreated-control and treated paired plots for each sampling period within each of the four years. Period A (pre-treatment) was used as a covariate within period B (post-treatment) analysis. Statistical significance was determined at $\alpha = 0.05$.

Results

Alexander State Forest

Overall analysis of period A samples at Alexander State Forest detected no significant difference in mean number of individual RIFA foragers collected in ant vials between untreated-control (155.49 ± 16.03, Mean ± SE) and treated plots (203.73 ± 18.65, $F_{1,6} = 2.36$, $P = 0.07$). Additionally, there was no significant difference found in mean number of RIFA between untreated-control and treated plots for any of the period A sampling dates (Table 2.1).

Table 2.1. Comparison of mean number of RIFA on untreated-control and treated paired plots for period A at Alexander State Forest.

Date	Num DF	Den DF	Treated (Mean ± SE)	Untreated-Control (Mean ± SE)	F Value	P Value
February 2002	1	5.37	200.87 ± 33.82	148.93 ± 31.05	0.54	0.48
June 2002	1	5.37	364.97 ± 41.15	195.93 ± 42.03	4.92	0.07
September 2002	1	5.37	474.20 ± 48.50	386.83 ± 46.49	0.59	0.47
October 2002	1	5.37	170.57 ± 38.89	157.03 ± 35.63	0.25	0.63
January 2003	1	5.37	0.60 ± 0.39	2.87 ± 2.63	0.05	0.83
March 2003	1	5.37	11.17 ± 4.20	41.33 ± 13.91	1.31	0.30

Period B began in April 2003 following the first Amdro® treatment at Alexander State Forest. Significant RIFA suppression on treated plots was achieved in 2003 and 2005. Collectively, analyses during the first year of period B (2003) detected mean numbers of RIFA collected from ant vials were significantly higher on untreated-control plots (232.06 ± 16.64) compared with treated plots (89.93 ± 12.29, $F_{4,19} = 13.25$, $P < 0.0001$). Similarly, in 2005 mean numbers of RIFA on untreated-control plots (204.27 ± 15.33) were significantly higher than treated plots (49.78 ± 9.55, $F_{6,24} = 4.98$, $P = 0.0019$). During 2004 no significant difference was shown between untreated-control (193.02 ± 15.59) and treated plots (50.54 ± 10.56, $F_{5,20} = 2.24$,

$P = 0.09$); although once treatments began at Alexander State Forest, higher mean numbers of RIFA were collected on untreated-control plots for every consecutive sampling date (Figures 2.4, 2.5, and 2.6).

Analysis of each 2003 sample separately revealed 98, 75, and 66% higher mean numbers of RIFA on untreated-control plots compared with treated plots in April, June, and October, respectively. The first two samples (April and June 2003) following the April 2003 treatment showed RIFA means to be higher on untreated-control plots (299.93 ± 31.74, and 290.60 ± 29.29, respectively) compared with treated plots (6.5 ± 5.9 and 71.40 ± 21.58; $F_{1,19} = 87.95$ and $F_{1,19} = 26.10$; $P < 0.0001$, respectively, Figure 2.4). Treatment with Amdro® was again administered in August 2003. However, the August 2003 RIFA sample showed no significant difference between untreated-control (300.37 ± 39.54) and treated plots (280.1 ± 32.10, $F_{1,19} = 0.28$, $P = 0.60$, Figure 2.4). In October 2003, following a third treatment, RIFA means were again shown to be significantly higher on untreated-control plots (265.80 ± 37.50) compared with treated plots (90.73 ± 24.0, $F_{1,19} = 18.66$, $P = 0.0004$, Figure 2.4). In December 2003, due to low sample size no significant difference was detected between untreated-control (3.6 ± 2.25) and treated plots (0.93 ± 0.84, $F_{1,19} = 0.69$, $P = 0.42$, Figure 2.4).

June and August 2004 analyses showed 95 and 82% higher mean numbers of RIFA on untreated-control plots compared with treated plots. In response to the May 2004 treatment, mean numbers of RIFA in June and August on untreated-control plots (304.67 ± 40.37 and 272.10 ± 44.64, respectively) were significantly higher compared to treated plots (15.1 ± 13.46 and 48.23 ± 24.68; $F_{1,17.4} = 13.86$, $P = 0.0016$ and $F_{1,17.4} = 9.41$, $P = 0.0068$, respectively, Figure 2.5). March, April, and October samples showed no significant difference between untreated-control (56.73 ± 18.47, 96.5 ± 18.48, and 239.5 ± 46.71, respectively) and treated plots (0.23 ±

0.20, 46.07 ± 17.66, and 193.60 ± 45.83; $F_{1,17.4}$ = 2.59, P = 0.13, $F_{1,17.4}$ = 0.41, P = 0.53, and $F_{1,17.4}$ = 0.56, P = 0.47, respectively, Figure 2.5).

During 2005, from April to October, mean numbers of RIFA ranged from 99 to 69% higher on untreated-control plots compared with treated plots. The first two samples in 2005 (January and March) showed no significant difference between untreated-control (158.67 ± 34.11 and 70.57 ± 18.28, respectively) and treated plots (99.0 ± 45.33 and 35.7 ± 15.92; $F_{1,11.6}$ = 1.89, P = 0.19 and $F_{1,11.6}$ = 0.51, P = 0.50, respectively, Figure 2.6). In April, May, July, and October mean RIFA numbers on untreated-control plots (296.67 ± 48.48, 356.43 ± 25.20, 249.37 ± 31.26, and 295.67 ± 53.29, respectively) were significantly higher than on treated plots (64.20 ± 17.67, 71.93 ± 29.96, 77.60 ± 27.73, and 0.03 ± 0.03; $F_{1,11.6}$ = 10.38, P = 0.007, $F_{1,11.6}$ = 17.27, P = 0.0014, $F_{1,11.6}$ = 8.5, P = 0.0133, and $F_{1,11.6}$ = 32.39, P = 0.0001, respectively, Figure 2.6). The last sample (December 2005) detected no significant difference between untreated-control (2.5 ± 2.30) and treated plots (0 ± 0, $F_{1,11.6}$ = 0.31, P = 0.59, Figure 2.6).

<u>Sandy Hollow WMA</u>

Overall analysis of period A at Sandy Hollow WMA detected mean RIFA numbers to be significantly higher on untreated-control plots (175.86 ± 15.71) compared with treated plots (118.76 ± 14.09, $F_{5,20}$ = 5.0, P = 0.0039). Both the April and September samples in 2002 showed significantly higher mean numbers of RIFA on untreated-control plots (288.10 ± 25.33 and 235.43 ± 39.5, respectively) compared with treated plots (34.10 ± 11.22 and 111.97 ± 40.07; $F_{1,13.2}$ = 0.00, P = 0.97 and $F_{1,13.2}$ = 6.42, P = 0.02, respectively, Figure 2.7). During January, June and December 2002, and February 2003 no significant difference was detected between untreated-control (125.87 ± 26.76, 392.67 ± 43.91, 0 ± 0, and 13.07 ± 6.91, respectively) and treated plots (145.20 ± 27.10, 372.33 ± 36.39, 6.90 ± 6.66, and 42.07 ± 19.78; $F_{1,13.2}$ = 0.29, P =

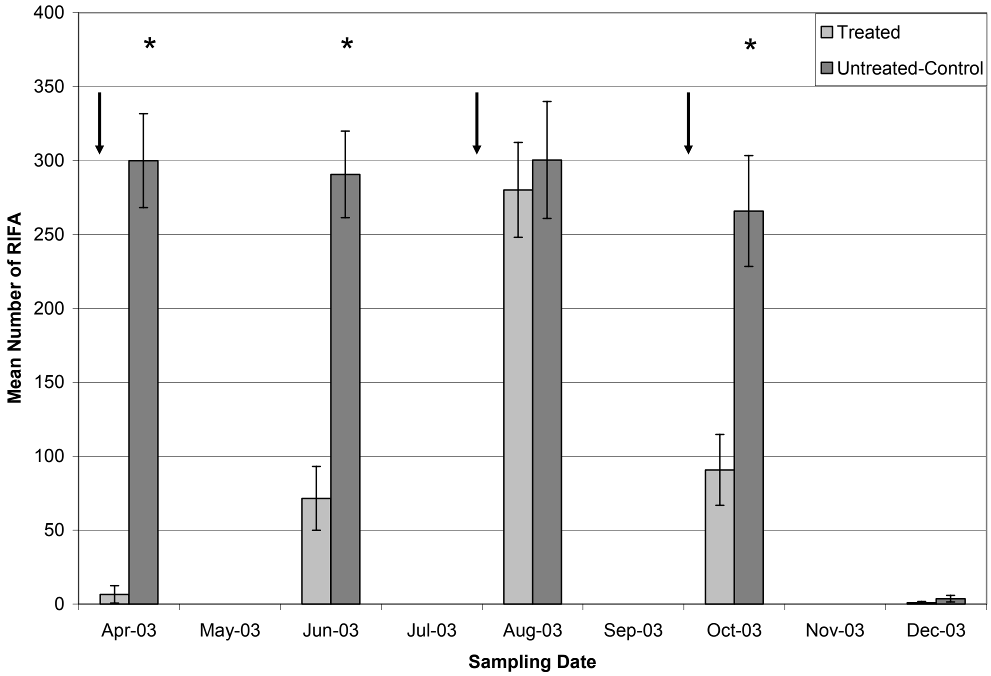


Figure 2.4. Mean number of RIFA on untreated-control and treated plots during 2003 at Alexander State Forest. Arrows designate months treatments were conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

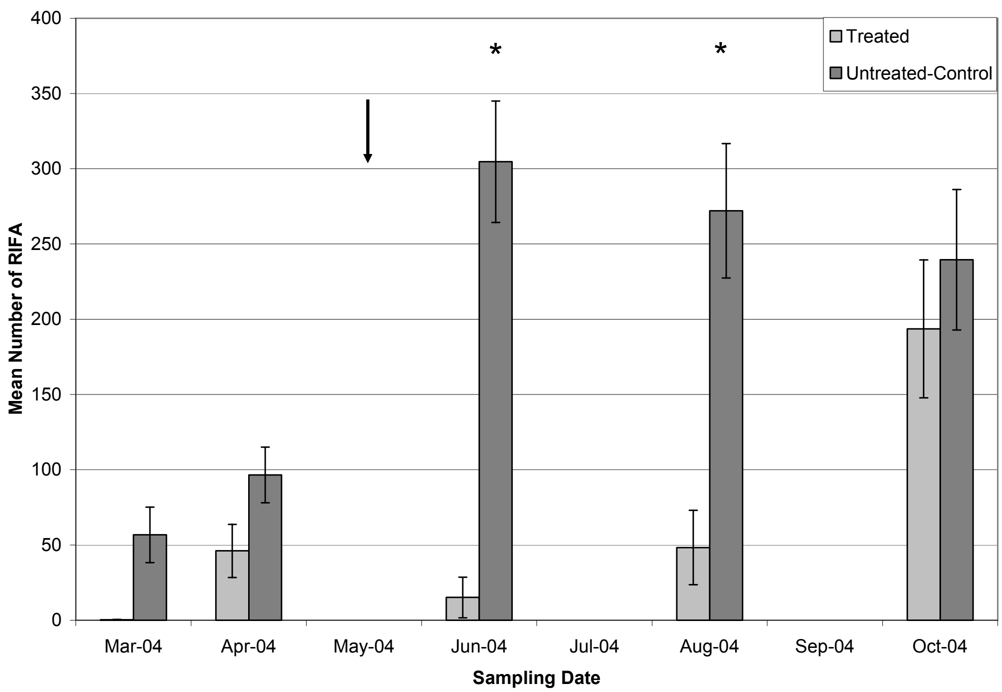


Figure 2.5. Mean number of RIFA on untreated-control and treated plots during 2004 at Alexander State Forest. Arrow designates month treatment was conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

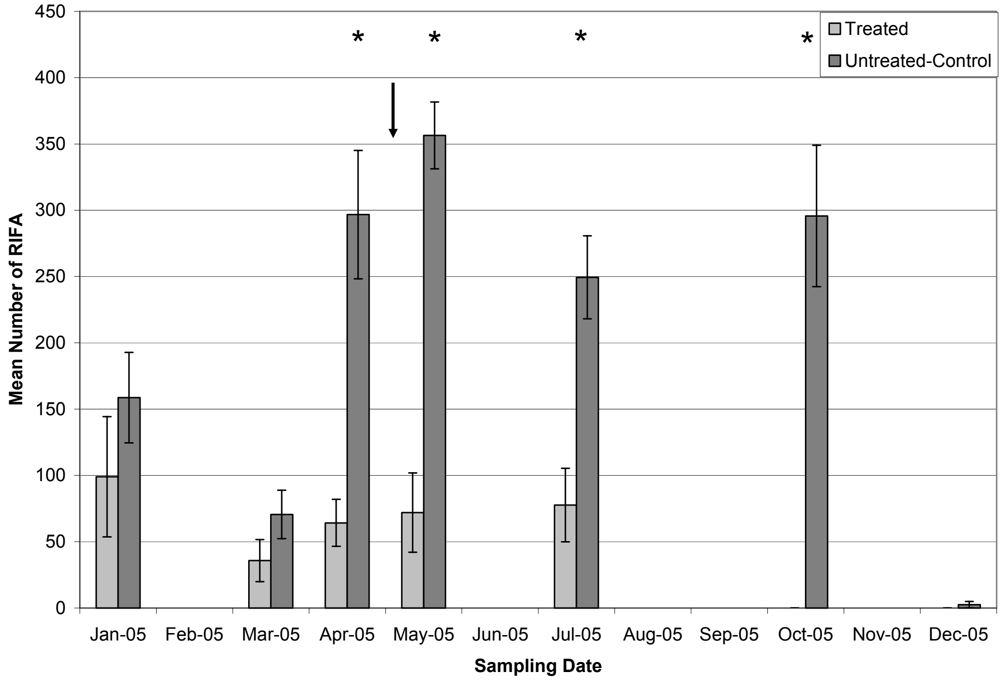


Figure 2.6. Mean number of RIFA on untreated-control and treated plots during 2005 at Alexander State Forest. Arrow designates month treatment was conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

0.60, $F_{1,13.2} = 0.00$, P = 0.97, $F_{1,13.2} = 0.31$, P = 0.59, and $F_{1,13.2} = 0.89$, P = 0.36, respectively, Figure 2.7).

Period B began in April 2003 following the first Amdro® treatment at Sandy Hollow WMA. Significant RIFA suppression was achieved in 2004 and 2005. Collectively, samples in 2003 showed no significant difference between untreated control (238.91 ± 17.36) and treated plots (155.96 ± 14.02, $F_{4,17.1} = 2.31$, P = 0.099). In 2004 and 2005 significantly higher mean numbers of RIFA were detected on untreated-control (225.34 ± 16.13 and 198.59 ± 16.27, respectively) compared with treated plots (53.97 ± 7.63 and 61.62 ± 9.18; $F_{6,24} = 11.53$, P < 0.0001 and $F_{5,20} = 8.43$, P = 0.0002, respectively).

Analysis of each of five samples collected in 2003 showed that significant suppression of RIFA was only achieved in May, despite treatments in April, August, and October. The May

RIFA sample showed a 55% higher mean number of RIFA on untreated-control plots (262.57 ± 27.93) compared with treated plots (119.37 ± 23.07, $F_{1,18.8} = 6.56$, $P = 0.0192$, Figure 2.8). No significant difference was found in April, August, October, and December between untreated-control (307.77 ± 24.22, 432.5 ± 39.87, 191.73 ± 35.54, and 0 ± 0, respectively) and treated plots (239.17 ± 25.64, 276.20 ± 34.60, 145.07 ± 32.17, and 0 ± 0; $F_{1,18.8} = 0.23$, $P = 0.63$, $F_{1,18.8} = 2.81$, $P = 0.11$, $F_{1,18.8} = 0.07$, $P = 0.79$, and $F_{1,18.8} = 0.73$, $P = 0.40$, respectively, Figure 2.8).

In 2004, despite a May Amdro® treatment, no significant difference was detected in February, April, and June between untreated-control (0.07 ± 0.05, 230.23 ± 20.92, and 234.23 ± 33.17, respectively) and treated plots (0 ± 0, 130.03 ± 20.9, and 148.03 ± 29.52; $F_{1,14.2} = 0.0$, $P = 0.97$, $F_{1,14.2} = 1.73$, $P = 0.21$, and $F_{1,14.2} = 0.61$, $P = 0.45$, respectively, Figure 2.9). In response to a change in treatment regimes (evening instead of morning treatments) in June, samples collected in July, August, and October showed (97, 94, and 71%, respectively) higher mean numbers of RIFA on untreated-control plots (475.67 ± 35.1, 440.63 ± 40.1, and 196.57 ± 38.1, respectively) compared with treated plots (14.57 ± 9.90, 28.43 ± 15.23, and 56.73 ± 22.81; $F_{1,14.2} = 45.58$, $P < 0.0001$, $F_{1,14.2} = 35.62$, $P < 0.0001$, and $F_{1,14.2} = 6.96$, $P = 0.02$, respectively, Figure 2.9). In December, no RIFA were collected on untreated-control or treated plots, so no significant difference was detected ($F_{1,14.2} = 0.01$, $P = 0.93$, Figure 2.9).

Due to success in 2004, treatments were again administered in the evening, in May and September 2005. No significant difference was detected between untreated-control (6.53 ± 4.05) and treated plots (14.87 ± 7.36) in March ($F_{1,21.7} = 0.00$, $P = 0.95$). However, samples collected in April, May, July, and October showed (48, 96, 55, and 82%, respectively) higher mean numbers of RIFA untreated-control plots (248.70 ± 20.95, 310.87 ± 25.63, 361.50 ± 41.40, and 263.93 ± 52.54, respectively) than on treated plots (129.73 ± 22.84, 12.70 ± 6.55, 164.33 ± 30.65, and 48.1

± 27.27; $F_{1,21.7} = 6.63$, $P = 0.02$, $F_{1,21.7} = 56.3$, $P < 0.0001$, $F_{1,21.7} = 11.47$, $P = 0.003$, $F_{1,21.7} = 22.34$, $P = 0.0001$, respectively). Similar to 2004, in December no RIFA were collected on untreated-control or treated plots, therefore no significant difference was detected ($F_{1,21.7} = 0.06$, $P = 0.813$).

Discussion

The efficacy of Amdro® has been tested by several researchers: Manely (1982), Apperson et al. (1984), Lofgren et al. (1985), and Collins et al. (1992). Excluding Manely (1982), who treated random mounds in various locations, all these studies were conducted in pastures, on plots that ranged from 0.2 to 0.8 ha (0.49 to 1.98 acres). Studies testing the efficacy of Amdro® on community-level RIFA suppression are not present in the literature. Moreover, published studies on RIFA suppression in habitats other than pastures have not been conducted. This four-year study was conducted in order to test the efficacy of Amdro® on a larger scale (2.02 ha) than previously tested, in two pine-dominated ecosystems.

Alexander State Forest is a homogenous mixed pine-hardwood site with a dense mid- and under-story. As expected, within a homogenous habitat, no significant difference in RIFA numbers between untreated-control and treated plots were detected during period A (pre-treatment).

Once period B began with the April 2003 treatment, significant RIFA suppression was achieved in 2003 and 2005. In 2003, RIFA suppression ranged from a maximum of 98% to a minimum of 66% between treated and untreated-control plots with suppression lasting a maximum of three months (Figure 2.4). Similarly, in 2005, RIFA suppression ranged from 99 to 69% with suppression lasting a maximum seven months. These results are supported by Collins et al. (1992) who found that following treatment with Amdro® RIFA suppression ranged from

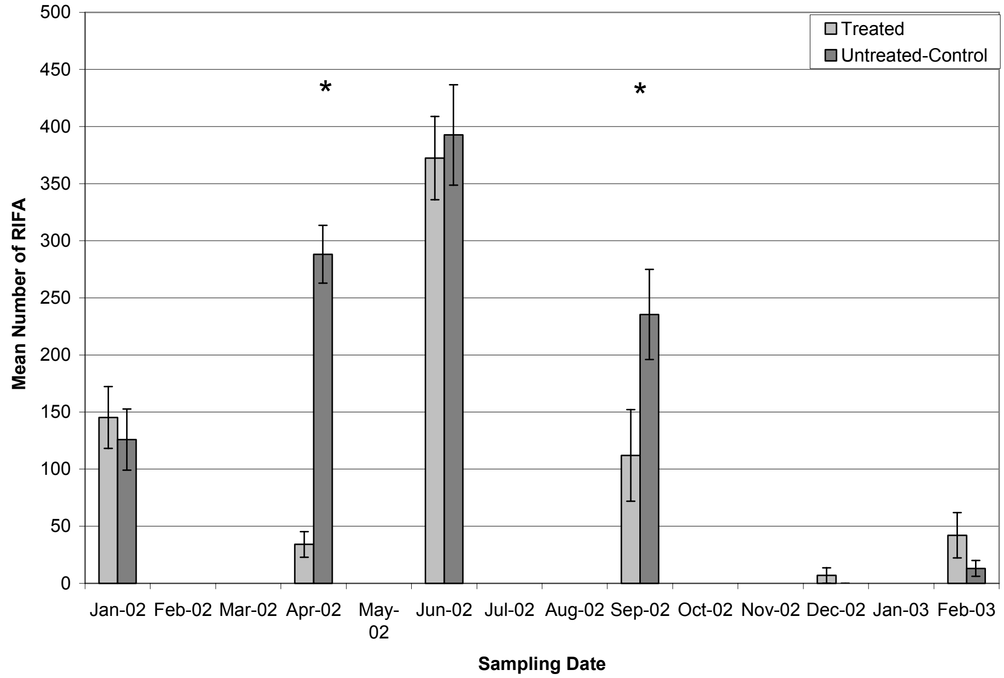


Figure 2.7. Mean number of RIFA on untreated-control and treated plots during period A at Sandy Hollow WMA. Asterisks designate significance at α = 0.05 and bars represent standard error.

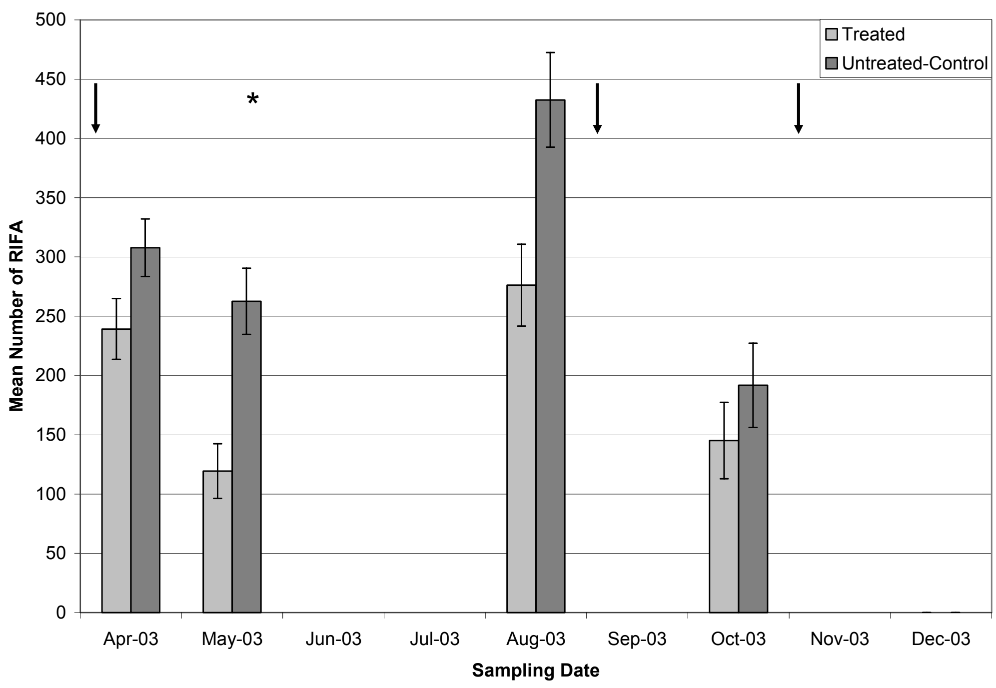


Figure 2.8. Mean number of RIFA untreated-control and treated plots during 2003 at Sandy Hollow WMA. Arrows designate months treatments were conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

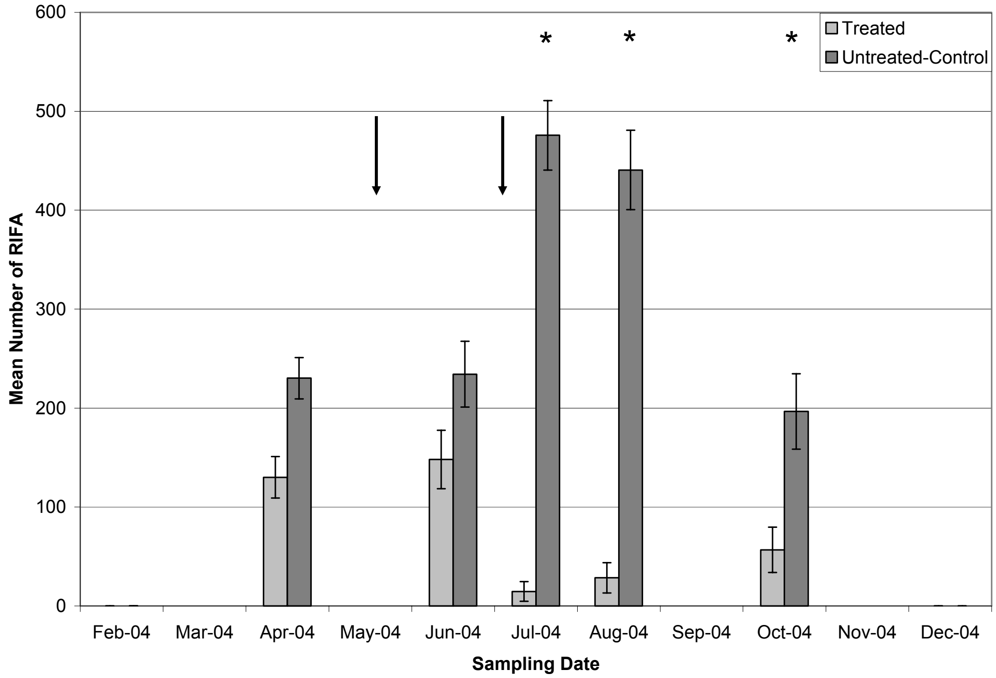


Figure 2.9. Mean number of RIFA on untreated-control and treated plots during 2004 at Sandy Hollow WMA. Arrows designate months treatments were conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

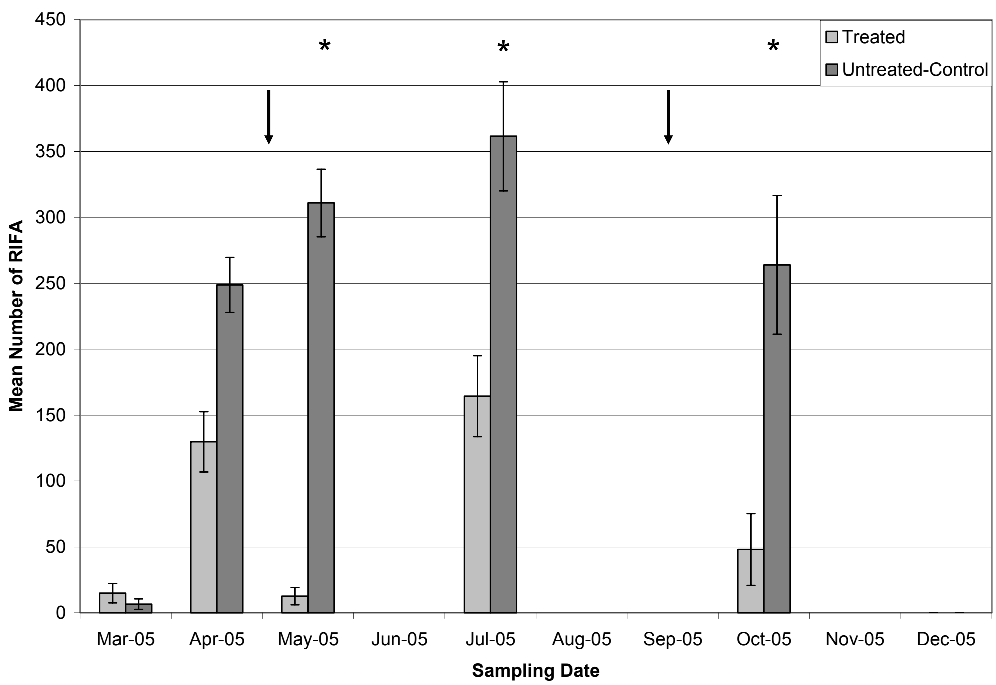


Figure 2.10. Mean number of RIFA on untreated-control and treated plots during 2005 at Sandy Hollow WMA. Arrows designate months treatments were conducted, asterisks designate significance at α = 0.05, and bars represent standard error.

91.3 to 42.3%. However, Collins et al. (1992) and Lofgren et al. (1985) found length of suppression to range from 4.75 to 11 months, which is longer than what was detected at Alexander State Forest. This may be because of differences in habitat type between the studies, pastures vs. pine-hardwood forest, with pine-hardwood forest being more complex habitats.

Based on the results from Alexander State Forest significant RIFA suppression can be achieved within a mixed pine-hardwood habitat, with a dense mid- and under-story, using broadcast applications of Amdro® at a rate of 1.68 kg/ha (1.5 lb/acre) once every three to seven months.

Sandy Hollow WMA is a savanna-type habitat primarily consisting of longleaf-pine with sparsely scattered hardwoods. The area is managed mainly for quail and dove, thus it is burned on a regular schedule leaving essentially no mid-story and an early-successional under-story. With the yearly to bi-yearly burn regime, RIFA thrive in Sandy Hollow WMA due to the constant disturbance. Unexpectedly, during period A (pre-treatment), significantly higher mean numbers of RIFA were found on untreated-control plots compared with treated plots even though the treatments were assigned randomly. Since period A was used as a covariate within the model, mean number of RIFA for period B analyses were corrected for differences in means numbers of RIFA in period A.

During period B significant suppression of RIFA was achieved in 2004 and 2005. Only one significant suppression period was achieved between April 2003 to July 2004; in May 2003, 55% more RIFA were collected on untreated-control plots compared with treated plots. Treatments from April 2003 to June 2004 were administered before daylight which gave RIFA only a few hours to forage before sunlight contacted the bait. Since results have shown that hydramethylnon will photodegrade rapidly (Vander Meer et al. 1982), combined with the openness of the canopy and absence of mid-story at Sandy Hollow WMA all succeeding treatments (beginning June 2004) were administered in the evening, allowing RIFA hours to forage before sunlight could contact the bait.

Once treatments began being administered in the evening RIFA suppression ranged from 97 to 71% in 2004 and 96 to 48% in 2005. Maximum length of suppression lasted for four months in 2004 and six months in 2005. Similar to findings at Alexander State Forest, results on percent suppression are supported by Collins et al. (1992), but length of suppression is still shorter than findings proposed by Collins et al. (1992) and Lofgren et al. (1985), at Sandy Hollow WMA.

Early results may indicate the photodegradation of hydramethylnon, but later results indicate that treatments administered in the evening can significantly suppress mean RIFA numbers in continuously disturbed, open habitats.

The research presented here supports the efficacy Amdro® (A.I. 0.7% hydramethylnon) with regular (habitat dependent) broadcast treatments, administered at dusk, at a rate of 1.68 kg/ha (1.5 lb/acre). Research on landscape-scale efficacy of Amdro®, over a long temporal scale, and within multiple habitats deserves further attention. Lofgren et al. (1975) stated that foraging tunnels for RIFA can extend 15 to 25 m (49 to 82 feet) from a single colony. Since single colonies can forage this distance Martin et al. (1998) suggested a treatment buffer zone of 35 to 40 m (115 to 131 feet). Large-scale suppression of RIFA will allow researchers to adequately monitor the impact this species pose on other taxa.

Chapter 3.

Impacts of Red Imported Fire Ants on Native Cotton Mouse (*Peromyscus gossypinus* Le Conte) Communities in Longleaf-pine and Pine-hardwood Forests

Introduction

Due to their wide range of life-history strategies and rapid response to community perturbations, small mammals have been ideal subjects in previous studies that investigated effects of RIFA invasion on native vertebrates (Killion et al. 1990). RIFA favor open and semi-open habitats, a preference they share with many wildlife species (Allen et al. 1994). The ant's optimum temperature range of 22-36º C (71-98° F) for foraging also coincides with peak reproductive activity of many vertebrate species (Allen et al. 1994). Nevertheless, small mammals avoid areas where RIFA are abundant (Killion and Grant 1993, Smith et al. 1990). In the presence of RIFA, Holtcamp et al. (1997) observed that deer mice (*Peromyscus maniculatus* Wagner) harvested a greater proportion of seeds from, spent more time in, and made more visits to rich feeding patches than to poor. In a laboratory-based experiment with a Y-maze, northern pygmy mice (*Baiomys taylori* (Thomas)), avoided 71% or significantly more situations that led to interactions with RIFA; however, no significant relationships were observed in the field (Lechner and Ribble 1996). Orrock and Danielson (2004) showed that in the presence of RIFA the oldfield mouse (*Peromyscus polionotus* (Wagner)), foraged less and in more exposed microhabitats than in the absence of RIFA.

Few studies have investigated impacts of RIFA on hispid cotton rats (*Sigmodon hispidus* Say and Ord). RIFA has the potential to significantly alter habitat-use patterns of cotton rats (Pedersen et al. 2003). Flickinger (1989) observed RIFA biting, stinging, and transporting tissue from live-trapped cotton rats. In a field study where 31 small mammal captures were made in a RIFA infested field, 74% of captures were badly mutilated by RIFA; some captures could only be identified by cranial characters (Chabreck et al. 1986). Conversely, Johnson (1961) determined that RIFA posed little importance as a predator to cotton rats and that RIFA mound densities did not correlate with cotton rat captures (Ferris et al. 1998).

In a study with cottontail rabbits (*Sylvilagus floridanus* (Allen)), Hill (1969) observed that >25% of litters in penned enclosures were destroyed by RIFA. Allen et al. (1997) found that white-tailed deer (*Odocoileus virginianus* (Boddaert)) fawn recruitment was reduced by RIFA infestation, and recommend suppression of RIFA since it would double fawn recruitment in treated areas. RIFA biting and stinging of deer fawns while they are resting can result in movements by fawns away from otherwise safe resting sites (Mueller et al. 2001).

Avian species also are impacted by RIFA and most studies present in the literature focus on Northern Bobwhite Quail (Allen et al. 2000 and Allen et al. 2004). The greatest impacts to quail occur during hatch, when RIFA will enter pipped eggs and consume chicks and when female quail may desert nests due to harassment from RIFA (Travis 1938). Giuliano et al. (1996) showed that exposure to as few as 50 RIFA for sixty seconds and 200 RIFA for fifteen seconds negatively affected survival of quail chicks, and chick exposure to 200 RIFA for sixty seconds lowered body mass of chicks when compared with controls. RIFA alter daily activity budgets of quail. Time spent by pen-raised chicks responding to RIFA negatively affected the allotment of time to other behaviors (Pedersen et al. 1996). Mueller et al. (1999) documented twice as many quail chicks surviving in plots treated for RIFA, after three weeks post-hatch, compared with controls. They also documented a live capture of a quail chick with its eyes swollen shut and swollen feet from RIFA stings; one RIFA was still stinging the chick's foot (Mueller et al. 1999). Allen et al. (1995) documented an increase in autumn quail densities after two years of fire ant suppression on treated compared with untreated-control plots.

Other species of birds that have been studied with respect to RIFA impacts including a few species of nesting waterbirds, Loggerhead Shrikes, *Lanius ludovicianus* Linnaeus, Least Terns, *Sterna antillarum* (Lesson), Barn Swallows, *Hirundo rustica* Linnaeus, Crested Caracaras, *Caracara plancus* (Miller), Common Ground Doves, *Columbina passerina* (Linnaeus), Black Rails, *Laterallus jamaicensis* (Gmelin), and Black-capped Vireos, *Vireo atricapillus* Woodhouse (Drees 1994, Morisawa 2000, and Allen et al. 2004). Drees (1994) showed that nesting waterbirds, such as Great Egerets, *Casmerodius albus* (Linnaeus), and Great Blue Herons, *Ardea herodis* (Linnaeus), responded to RIFA suppression with a 92% increase in offspring production. Cliff Swallow (*Hirundo pyrrhonota* Vieillot) nest success has been documented dropping 34.4-30.5% after RIFA establishment in Burleson and Washington counties, in Texas (Anonymous 1986). Lockley (1995) observed RIFA stinging and killing Least Tern chicks in Harrison county, Mississippi. The effects of RIFA on wildlife populations are still poorly understood; the research that has been conducted on impacts of RIFA on mammals has been observational, opportunistic, and small-scale experiments (Allen et al. 1994, Allen et al. 2004).

Throughout the southeastern United States, cotton mice (*Peromyscus gossypinus* LeConte) are among the most abundant mammals. The geographic range of this species extends northward from the Gulf of Mexico to southeastern Virginia and southern Illinois, and westward from the Atlantic Ocean to eastern Texas and southern Oklahoma (Wolfe and Linzey 1977). Cotton mice are medium-sized rodents (17-46 grams) colored dark golden-brown above with a dusky middorsal area that extends from the shoulders to the base of the tail (Wolfe & Linzey 1977). The under-parts and feet are white with a sparsely-haired tail, that is shorter than the body, dark above and fading to off-white below (Wolfe and Linzey 1977).

Cotton mice are an omnivorous species that occupies numerous habitats throughout its range. Its preferred habitat is classified as bottomland hardwood forest, but they are known to occur in mesic and hydric hammocks, swamps, cleared fields, pine and salt savannas, upland pine communities, beach dunes and palmetto thickets bordering beaches (Pournell 1950, McCarley 1954 and 1959, Layne 1974, Gentry et al. 1968, Ivey 1949, Shadowen 1963). Cotton mice have been shown to be adept at swimming (Calhoun 1941) as well as agile climbers; both are behaviors that increase the availability of suitable habitats to this species (Ivey 1949, Pournelle 1950). Pournelle (1950) released a cotton mouse on the trunk of a tree, eight feet above ground level, and observed that the mouse immediately ascended toward the top of the tree in a spiral fashion similar to that of a squirrel. The omnivorous nature of this species also increases the amount of suitable habitats in which it can occupy. Calhoun (1941) classified cotton mice not only as omnivorous but as opportunistic foragers, suggesting that availability of prey ultimately determined diet. He observed the stomach contents of a series of cotton mice in Tennessee and found that 68% of the animal matter was arthropods from the groups Coleoptera, Lepidoptera and Araneida.

Cotton mice have sympatric ranges with eleven other species from family Muridae (rats, mice, voles and lemmings) in Louisiana. Most notable of which, is sympatric ranges with white-footed mice, *Peromyscus leucopus* (Rafinesque). Cotton mice and white-footed mice are assumed to compete for resources and are normally separated ecologically when their ranges overlap (McCarley 1954). The two species have been known to hybridize successfully, but the majority of hybridizations between the two species are infertile (Taylor and McCarley 1963). In a penned enclosure Taylor and McCarley (1963) showed that when cotton mice and white-footed mice co-occur that the two species will spatially separate themselves vertically. They found that when the two species were placed in a pen separately with ample ground and elevated nest boxes that both the white-footed mice and cotton mice chose elevated nest boxes 90% and 93% of the time, respectively. When the two species were placed in the pen together white-footed mice still favored the elevated nest boxes while 75% of the cotton mice separated themselves in ground nests (Taylor and McCarley 1963). However, this study was conducted in penned enclosures in absence of RIFA; its possible cotton mice may prefer elevated nests in presence of RIFA regardless of sympatric ranges with white-footed mice.

Most of the literature on the life-history strategies of this species was published from 1950 to 1970 with the majority of the studies taking place in Florida and Texas -extremes of cotton mice range. In Florida, Texas, and Louisiana studies have all concluded that cotton mice show peak populations from January to March yearly with lowest populations in June, July and August (Pournelle 1952, McCarley 1954 and 1959, Shadowen 1963). Pournelle (1952) observed that males will not breed (become sterile) at temperature of 31.7º - 38.3 ºC (89º - 101ºF) but will breed at 20º - 28.9ºC (68º - 84ºF). In Texas, peak breeding season occurs in late fall or early winter, although breeding has been observed as early as September (McCarley 1954).

Cotton mice breeding cycles have been well documented. Male cotton mice are promiscuous and no known cases of pair bonding between males and females have been observed (McCarley 1959). Males reach sexual maturity at 45-70 days old while females are sexually mature at approximately 43 days (McCarley 1959). Pournelle (1952) observed that females have an average estrous cycle of 5.26 days and will cycle approximately every four to six days until they are bred. Females gestate approximately 23 days and produce average litter sizes of 3.7 individuals (Pournelle 1952). In Pournelle's (1952) study in north Florida average sex ratio did not differ from 50:50, but by comparison Layne (1974) found an average sex ratio of 67:33 (males/females) in flatwoods habitat in north-central Florida. Young mice are normally weaned and leave their mother at 20-25 days of age (Pournelle 1952).

Densities and home range estimates of cotton mice vary depending on location. Cotton mice population densities in South Carolina have been estimated at 2.5-4.9/ha (1-1.96/acre, Gentry et al. 1968). Layne (1974) found that a maximum cotton mice density of 1.17/ha (0.47/acre) and an average home range of 0.18 ha (0.44 acres) in flatwoods habitat in Florida. In Louisiana maximum population densities have been estimated by Shadowen (1963) at 0.49/ha (0.20/acre). Layne (1974) and Shadowen (1963) have also both noted that prescribed fire has little effect on cotton mice population sizes; densities increase post-burn and individual residents of an area burned do survive the fire.

To assess the impact RIFA may pose on cotton mice communities in Louisiana, a baited trapping grid was used to monitor cotton mice numbers in response to RIFA suppression at Alexander State Forest and Sandy Hollow WMA.

Methods

Small Mammal Sampling

Sampling occurred for four consecutive years during the months of January/February (winter sample) and June/July (summer sample) at each site. Three small-mammal samples were collected during period A (winter 2002, summer 2002, and winter 2003) and five samples were collected during period B (summers 2003, 2004, 2005 and winters 2004, 2005). Sherman live traps (Figure 3.1) were set 10 m apart in a 5 x 5 grid formation (i.e. small-mammal grid) for four consecutive nights on both treatment and untreated-control plots. Bait made of equal parts of peanut butter and oats, wrapped in wax paper was secured at the rear of the trap. Traps were covered with sufficient vegetation to help prevent overheating or freezing of trapped mammals and checked every morning they were open (Permit WL-Research-2002-02). Talstar®, a granular contact insecticide (Talstar®, FMC Corporation), was used at 1.97 g/m^2 distributed over a 1 m radius around each trap to prevent predation of captured small mammals by RIFA (Landry 2004). Captured small mammals were weighed using a Pesola® spring balance, sexed, aged, marked by using the toe clip method and released (Rudran 1996). Weights, sex, and age provided additional confidence when assigning recaptures to previously captured individuals.

Figure 3.1. Sherman live trap surrounded and covered with grass to protect captured mammals from adverse weather conditions.

<u>Statistical Analysis</u>

Program MARK© was used to assess effects of RIFA on small mammal communities at Alexander State Forest and Sandy Hollow WMA. Within Program MARK© a robust design model with closed captures was chosen to estimate mean population sizes of cotton mice on treated and untreated-control plots for each small mammal sampling period at each field site. Seventeen models were fitted to the data for each field site and the most practical model was chosen based on corrected AIC (Akaike Information Criterion) value. AIC is a criterion that allows for comparison of the likelihood of two models and penalizes larger models with equal fit. Derived population estimates, covariances, and variances were then transferred to SAS version 9.1 software package (SAS Institute Inc. 2002). Within SAS, Wald test statistics were calculated to test statistical significance between treated and untreated-control plots for each sampling period and between periods A and B, at each field site. The Wald test calculates a Z statistic, and then squares it yielding a Wald statistic with a chi-square distribution. Statistical significance was considered at $P < 0.05$.

Regression analyses were also used within SAS to observe if mean numbers of cotton mice were associated with mean numbers of RIFA. Mean numbers of RIFA from sampling dates (Chapter 2) closest to that of small mammal sampling dates were used from untreated-control and treated plots. Regressions were performed from means of RIFA and mean population estimates of cotton mice at dates: within all period A and B untreated-control and treated samples; all untreated-control samples (period A and B); all treated samples (period A and B); period B treated samples; period B untreated-control samples; winter untreated-control and treated samples (period A and B); and summer untreated-control and treated samples (period A and B). An additional regression analysis of means number of RIFA and mean population estimates of cotton mice for 2004 and 2005 (once evening treatments began) was conducted at Sandy Hollow WMA.

Mean population densities were calculated for all small mammal species present during each trapping year, at Alexander State Forest and Sandy Hollow WMA. Mean population densities were calculated, for untreated-control and treated plots, by taking an average of the number of unique captures and recaptures, only from previous periods, for each year (period A, 2003, 2004, and 2005), then dividing by the number of untreated-control or treated plots (three), and finally dividing by two to get the number per hectare. Calculations were not made for southeastern shrews at Alexander State Forest and golden mice at Sandy Hollow WMA, due to low number of captures (Appendix B).

Results

Small mammal captures at Alexander State Forest consisted of 188 individuals comprising six species and 139 trapped individuals comprising four species at Sandy Hollow WMA (Appendix B). Cotton mice were the most consistently encountered species at both sites with 32.40% at Alexander State Forest and 67.00% of the total captures at Sandy Hollow WMA. Due to the number of individuals captured, the cotton mouse was the only species at either site that was able to be successfully modeled using Program MARK©.

Alexander State Forest

Collectively, mean cotton mice population estimates for period A at Alexander State Forest were significantly higher on untreated-control plots (6.31 ± 2.67, mean ± SE) compared with treated plots (1.67 ± 0.67, $\chi^2 = 74.71$, df = 1, $P < 0.0001$, Figure 3.2). Analysis of each of the three period samples revealed no significant difference in population estimates for both untreated-control (0.33 ± 0.00) and treated plots (0.33 ± 0.00) during the winter 2002 sample ($\chi^2 = 0$, df = 1, P = 1). However, the summer 2002 sample showed a significant difference between untreated-control plots (2.80 ± 0.36) and treated (0.33 ± 0.00, $\chi^2 = 47.41$, df = 1, $P < 0.0001$). The winter 2003 sample also yielded a significant difference between mean population estimates on untreated-control (3.17 ± 0.38) and treated plots (1.00 ± 0.00, $\chi^2 = 32.73$, df = 1, $P < 0.0001$).

Similar to period A at Alexander State Forest, collective population estimates of cotton mice for period B showed a significantly higher mean number on untreated-control plots (8.01 ± 2.13) compared with treated plots (3.43 ± 0.77, $\chi^2 = 79.77$, df = 1, $P < 0.0001$, Figure 3.2).

Summer 2003 was the only period B sample to detect a higher mean population estimate for treated plots (1.00 ± 0.00) compared to untreated-control (0.67 ± 0.00, χ^2 = 628004.49, df = 1, P < 0.0001). Winter and summer samples in 2004 and 2005 all showed a higher mean population estimate for untreated-control plots (2.05 ± 0.31, 2.80 ± 0.36, 5.04 ± 0.48, and 2.80 ± 0.36, respectively) compared with treated plots (0.67 ± 0.00, 1.33 ± 0.00, 2.05 ± 0.31, and 0.67 ± 0.00; χ^2 = 19.74, df = 1, P < 0.0001, χ^2 = 16.75, df = 1, P < 0.0001, and χ^2 = 29.17, 35.45 df = 1, P < 0.0001, respectively).

Regression analyses of mean numbers of RIFA and mean population estimates of cotton mice at each small mammal sampling date on untreated-control and treated plots for periods A and B, at Alexander State Forest, found no association between RIFA and cotton mice (R^2 = 0.0004, $F_{1,14}$ = 0.01, P = 0.94). Additionally, no relationship was found between mean number of RIFA and mean population estimates of cotton mice in all untreated-control samples, including period A (R^2 = 0.03, $F_{1,6}$ = 0.19, P = 0.68), untreated-control samples in period B (R^2 = 0.05, $F_{1,3}$ = 0.16, P = 0.72), or all treated plots in period B (R^2 = 0.39, $F_{1,3}$ = 1.94, P = 0.26). Similarly, no association was found in all samples on untreated-control and treated plots (period A and B), during winter (R^2 = 0.006, $F_{1,6}$ = 0.03, P = 0.86) and summer (R^2 = 0.00, $F_{1,6}$ = 0.00, P = 1.00).

Mean population densities for cotton mice, hispid cotton rats, and white-footed mice, at Alexander State Forest were lower on treated plots than on untreated-control plots (Table 3.1). Fulvous harvest mice and golden mice were the only species to show a higher mean density on treated plots compared with untreated-control plots (Table 3.1).

<u>Sandy Hollow WMA</u>

Collectively, mean cotton mice population estimates for period A at Sandy Hollow WMA showed no significant difference between untreated-control plots (9.28 ± 6.93) and treated

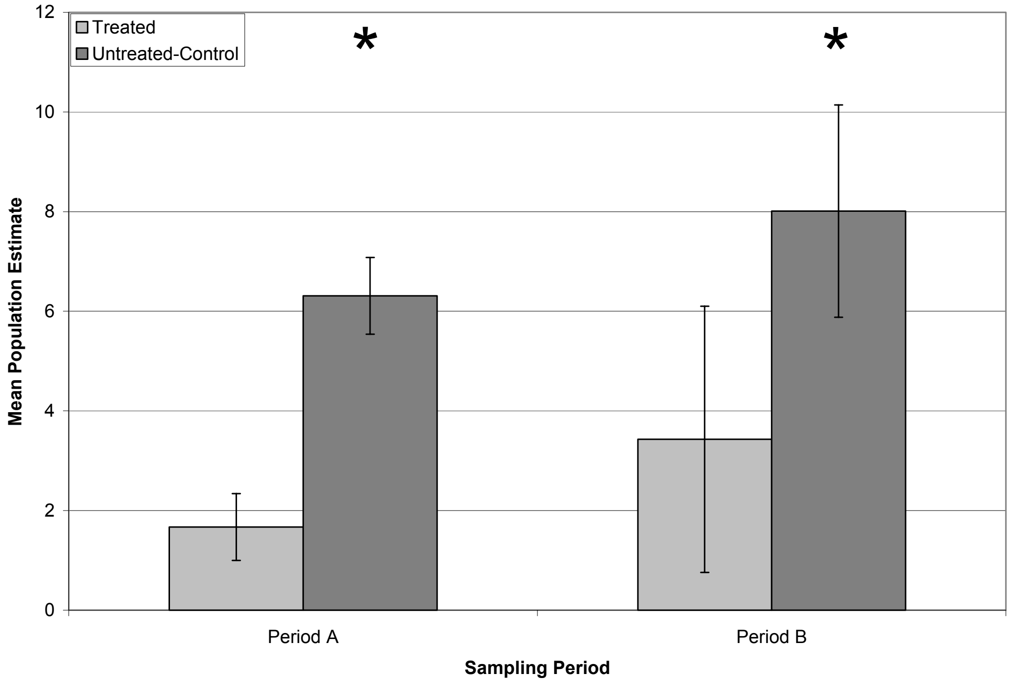


Figure 3.2. Mean population estimates of cotton mice on treated and untreated-control plots for pre-treatment (period A) and post-treatment (period B) at Alexander State Forest (* indicates significance difference between treated and untreated-control at $p < 0.0001$).

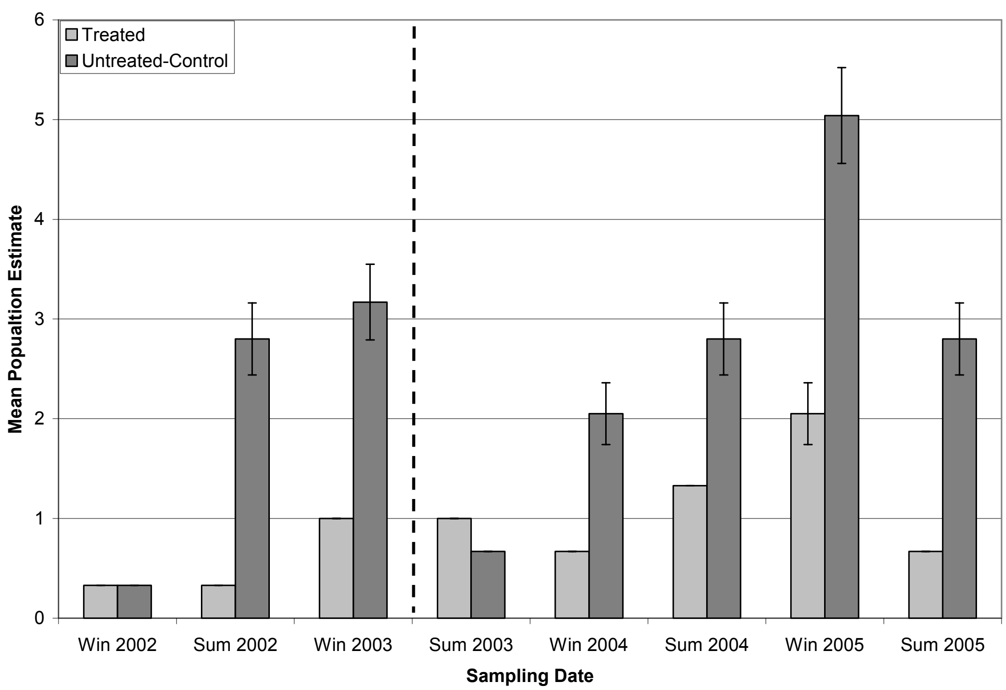


Figure 3.3. Mean population estimates of cotton mice on treated and untreated-control plots for each sample collected at Alexander State Forest. Dashed line divides period A (left) from period B (right).

Table 3.1. Mean population densities for small mammal species captured on untreated-control and treated plots at Alexander State Forest compared to that reported in the literature.

Species	Untreated-Control Num of Ind/ha	Treated Num of Ind/ha	Published Population Den
Cotton Mice	1.75	0.71	0.49-4.90/ha[1]
Fulvous Harvest Mice	0.57	0.67	5.75-28.00/ha[2]
Golden Mice	0.13	0.67	0.47-6.89/ha[3]
Hispid Cotton Rats	1.46	0.83	0.02-69.00/ha[4]
White-footed Mice	0.71	0.42	1.20-7.20/ha[5]

plots (8.17 ± 4.10, $\chi^2 = 1.97$, df = 1, P = 0.16, Figure 3.4). During the winter 2002 sampling period no individuals were trapped on either untreated-control or treated plots, therefore no difference was observed ($\chi^2 = 0.00$, df = 1, P = 1.00). Mean population estimates in summer 2002 were significantly higher for untreated-control plots (7.60 ± 0.57) compared with treated plots (3.90 ± 0.41, $\chi^2 = 30.19$, df = 1, P < 0.0001). However, the winter 2003 sample detected a significantly higher mean population estimate on treated plots (4.27 ± 0.42) compared with untreated-control plots (1.67 ± 0.03, $\chi^2 = 37.61$, df = 1, P < 0.0001).

Mean population estimates of cotton mice for all samples in period B, at Sandy Hollow WMA, showed a significantly higher mean number on treated plots (8.46 ± 3.25) compared with untreated-control (4.96 ± 1.87, $\chi^2 = 44.49$, df = 1, P < 0.0001, Figure 3.3). Analyses of summer 2003 and winter 2004 detected mean population estimates to be higher on treated plots (6.50 ± 0.52 and 1.67 ± 0.02, respectively) compared with untreated-control plots (3.53 ± 0.39 and 0.00 ± 0.00; $\chi^2 = 22.11$, df = 1, P < 0.0001 and $\chi^2 = 5446.69$, df = 1, P = 0.00, respectively).

Authors: [1]Wolfe and Linzey 1977, [2]Spencer and Cameron 1982, [3]Linzey and Packard, [4]Cameron and Spencer 1981, [5]Snyder 1956.

However, untreated-control (2.41 ± 0.33) and treated (2.41 ± 0.33) plots did not differ significantly during the summer 2004 sample ($\chi^2 = 0.00$, df = 1, P = 0.99). In winter 2005 mean population estimates of cotton mice were significantly higher on untreated-control plots (0.67 ± 0.00) compared with treated plots (0.00 ± 0.00, $\chi^2 = 12148065$, df = 1, P = 0). However, the summer 2005 sample showed mean population estimates to be significantly higher on treated plots (3.53 ± 0.39) compared with untreated-control plots (1.67 ± 0.02, $\chi^2 = 23.08$, df = 1, P < 0.0001).

Unexpectedly, regression analyses at each small mammal sampling date on untreated-control and treated plots for periods A and B, at Sandy Hollow WMA, found a positive association between mean numbers of RIFA and mean population estimates of cotton mice ($y = 0.01x + 0.92$, $R^2 = 0.49$, $F_{1,14} = 13.68$, P = 0.002). Similarly, a positive association between mean numbers of RIFA and mean population estimates of cotton mice was found for 2004 and 2005, when evening treatments commenced (Chapter 2) and significant suppression of RIFA was achieved ($y = 0.009x + 0.79$, $R^2 = 0.80$, $F_{1,4} = 16.33$, P = 0.02). A positive relationship was also detected between mean number of RIFA and mean population estimates of cotton mice in all untreated-control samples, including period A ($y = 0.01x + 0.89$, $R^2 = 0.44$, $F_{1,9} = 7.03$, P = 0.03). However, no association was detected in mean numbers of RIFA and mean population estimates of cotton mice for all untreated-control samples in period B ($R^2 = 0.76$, $F_{1,3} = 9.31$, P = 0.06), and all treated samples in period B ($R^2 = 0.56$, $F_{1,3} = 3.88$, P = 0.14). Similarly, no association was found in all period A and B winter ($R^2 = 0.05$, $F_{1,6} = 0.29$, P = 0.61) and summer ($R^2 = 0.48$, $F_{1,6} = 5.46$, P = 0.06) samples on untreated-control and treated plots,.

Mean population densities for cotton mice and hispid cotton rats were found to be higher on treated plots compared with untreated-control plots, at Sandy Hollow WMA (Table 3.2).

However, mean densities of white-footed mice were found to be higher on untreated-control plots compared with treated plots (Table 3.2).

Table 3.2. Mean population densities for small mammal species captured on untreated-control and treated plots at Sandy Hollow WMA compared to that reported in the literature.

Species	Untreated-Control Num of Ind/ha	Treated Num of Ind/ha	Published Population Den
Cotton Mice	1.96	2.54	0.49-4.90/ha
Hispid Cotton Rats	0.46	1.08	0.02-69.00/ha
White-footed Mice	0.17	0.13	1.20-7.20/ha

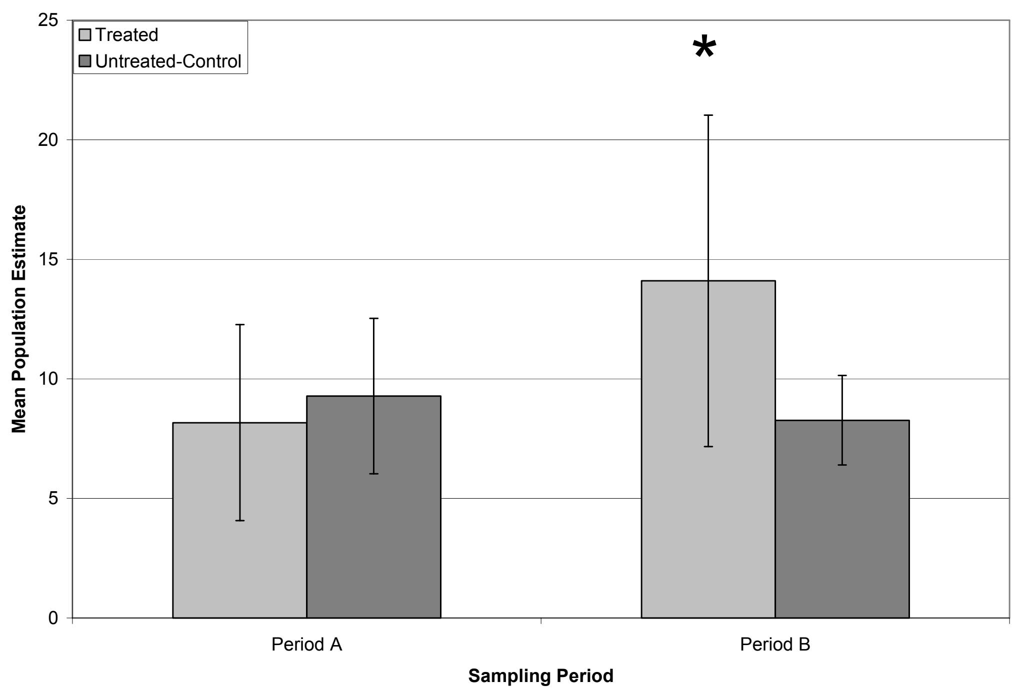


Figure 3.4. Mean population estimates of cotton mice on treated and untreated-control plots for pre-treatment (period A) and post-treatment (period B) at Sandy Hollow WMA (* indicates significance difference between treated and untreated-control at $p < 0.0001$).

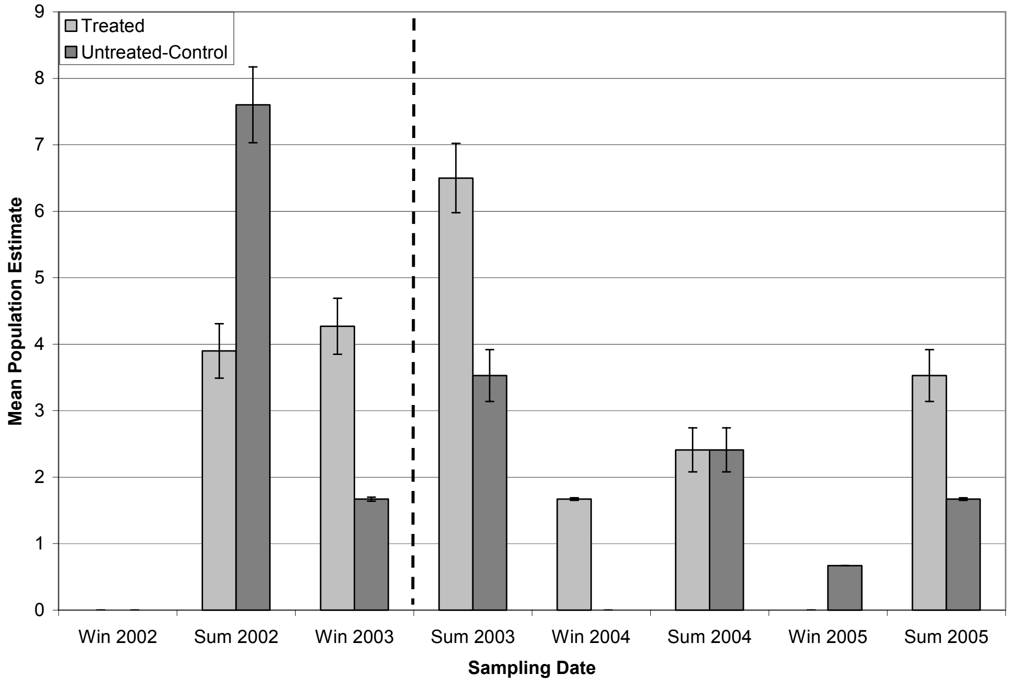


Figure 3.5. Mean population estimates of cotton mice on treated and untreated-control plots for each sample collected at Sandy Hollow WMA. Dashed line divides period A (left) from period B (right).

Discussion

Allen et al. (1994) stated, "that to gain an understanding of the effects of RIFA on vertebrates that we need long-term comprehensive ecological studies that encompass populations of target vertebrates, and are conducted with controls and adequate temporal and spatial replication (Hurlbert 1984)." This experiment was designed to measure the impact RIFA pose on small mammal communities in two pine-dominated ecosystems in Louisiana. Cotton mice made up the majority of small mammal captures at both field sites and were used as the focal species in this study. In the southeast United States cotton mice make ideal species to study with respect to impacts by RIFA. RIFA's range completely overlaps that of the cotton mice and both species are classified as opportunistic, omnivorous foragers, which inhabit a wide variety of habitats.

Cotton mice made up 32.4% of the captures at Alexander State Forest, with 73% of them caught on untreated-control plots throughout the study. Based on the results, RIFA pose minimal impacts on cotton mice at Alexander State Forest. Mean population estimates of cotton mice did not respond to RIFA suppression on treated plots and remained relatively stable on untreated-control plots (Figure 3.3). Fluctuations in cotton mice populations at Alexander State Forest may not be impacted by RIFA. This is supported by regression analyses that found no association between mean numbers of RIFA and mean population estimates of cotton mice for any set of sample dates analyzed. The difference in population estimates throughout this study may be due to natural fluctuations seen in numerous small mammal species (Terman 1966).

Cotton mice made up a higher percentage of the captures (67%) at Sandy Hollow WMA than at Alexander State Forest. As expected, during period A at Sandy Hollow WMA, no significant difference was detected in mean population estimates of cotton mice between untreated-control and treated plots (Figure 3.4). However, in period B, once RIFA suppression commenced, cotton mice population estimates were shown to be significantly higher on treated plots compared with untreated-control plots for three of the five sampling dates (Summers 2003 and 2005, and Winter 2004). As opposed to Alexander State Forest, RIFA may play a role in regulating cotton mice populations, although, regression analyses from Sandy Hollow WMA would contradict this statement. The regression of mean population estimates of cotton mice and mean numbers of RIFA for each sampling date found a positive association between cotton mice estimates and RIFA number. This assumes that whatever biotic or abiotic factor favoring cotton mice might also favor RIFA. Moreover, if period A and 2003 are removed from the regression a positive association is again detected between mean population estimates of cotton mice and mean numbers of RIFA for both untreated-control and treated plots. Based on the results, differences in mean population estimates of cotton mice at Sandy Hollow WMA, in period B, can likely be due to natural population fluctuations of cotton mice. If RIFA suppression is factored in (2004 and 2005), mean population estimates of cotton mice and mean numbers of RIFA show a positive relationship and maybe both responding positively to similar habitat conditions.

Habitat characteristics at Sandy Hollow WMA seem to favor both cotton mice and RIFA. Both species were found in higher overall abundance at Sandy Hollow WMA compared with Alexander State Forest (see Chapter 2 and Figures 3.3 and 3.4). RIFA thrive at Sandy Hollow WMA due to the periodic disturbance associated with the burn regime, while cotton mice, which are generalist foragers, greatly benefit from the abundance of early successional habitat.

Derived mean population densities of cotton mice at Alexander State Forest (0.71/ha on treated plots and 1.75/ha untreated-control plots) are comparable to those found by Layne (1974) and Shadowen (1963); whose studies in Florida and Louisiana estimated populations at 0.49/ha and 1.17/ha, respectively. However, derived population densities of cotton mice at Sandy Hollow WMA (2.54/ha on treated plots and 1.96/ha on untreated-control plots) are similar to what Gentry et al. (1968) showed to be 2.5-4.9/ha in South Carolina. Further research is still needed to ultimately determine the impacts RIFA may or may not pose on cotton mice populations. Minimally, monthly sampling needs to be conducted due to this species short lifespan. Longevity of cotton mice is relatively short in the field; longevity averages 1.7 months with a maximum of 5 months in Florida (Layne 1974). However, four captured individuals from Sandy Hollow WMA were known to survive for a year, and one individual from Alexander State Forest was captured for a year and a half. With enough effort RIFA can be suppress in both mixed pine-hardwood and longleaf-pine ecosystems (Chapter 2). Long-term suppression of RIFA combined with monthly sampling of cotton mice may further elucidate the impacts RIFA pose in these ecosystems.

Chapter 4.

Impacts of Red Imported Fire Ants on Native Herpetofauna Communities in Longleaf-pine and Pine-hardwood Forests

Introduction

Impacts of invasive species such as RIFA altering structure and function of native communities are widely recognized, yet little research has been conducted on RIFA invasion in native North American faunal communities (Killion et al. 1990). Introduced invasive species is one of the six accepted reasons proposed by the Partners in Amphibian and Reptile Conservation for the global decline of herpetofauna (Gibbons et al. 2000). Life history traits of herpetofauna such as egg laying, disturbance associated with nesting activity, and delayed hatchling emergence tend to make them particularly susceptible to RIFA (Allen et al. 1994, Allen et al. 2004). RIFA are attracted to the disturbance, mucous, and moisture associated with nests of many species of herpetofauna (Allen et al. 2001).

Often herpetofauna are most vulnerable to RIFA during the egg or hatchling stage. In a study of the slider turtle, *Trachemys scripta* (Schoepff), Buhlmann and Coffman (2001) used underground, infrared cameras to show that RIFA establish foraging tunnels into nests of slider turtles to investigate eggs to attack upon hatch. They found that fire ants attacked and killed young slider turtles upon hatching, and even before hatch, any eggs with imperfections such as cracks could be breeched by RIFA and consumed (Buhlmann and Coffman 2001). During a study in Florida, 98% of slider turtle nests were destroyed by mammalian predators and RIFA (Aresco 2004). Of that raccoons destroyed 94% while RIFA were responsible for destruction of the other 4%. Aresco (2004) also observed RIFA building mounds on newly constructed slider turtle nests. Other researchers have confirmed these findings in two other turtle species, the loggerhead (*Caretta caretta* Pension) and green, *Chelonia mydas* (Linnaeus) sea turtles (Parris et al. 2002, Allen et al. 2001). During a study with the red-bellied cooter (*Pseudemys nelsoni* Carr), Allen et al. (2001) found that over 70% of loggerhead sea turtle hatchlings were killed by RIFA during pipping or shortly after hatch. Parris et al. (2002) observed an average of 4.7% green sea turtle hatchling mortality in Florida. Aquatic turtles are not the only turtle species susceptible to RIFA; terrestrial turtles such as the gopher tortoise, *Gopherus polyphemus* (Daudin) are also negatively affected (Landers et al. 1980). Epperson and Heise (2003) found that 27% of gopher tortoise hatchling mortality is attributed to RIFA in southern Mississippi. Three-toed box turtles, *Terrapene carolina triunguis* (Agassiz) are not adapted to protect themselves from RIFA as young or adults, Montgomery (1996) observed 5 of 6 adult box turtles were destroyed by RIFA in a study, in Bastrop county, Texas.

Most published herpetofauna-fire ant interaction data is observational. Whiting (1994) observed that irritation caused by RIFA prevents the Texas river cooter (*Pseudemys texana* (Baur) from completion of nesting processes. Snapping turtle *Chelydra serpentine* (Linnaeus) nests were destroyed in Alabama, and eggs of the rough green snake, *Opeodrys aestivus* (Linnaeus) can be breeched and killed by RIFA (Conners 1998a and b). In a field setting, RIFA will attack and consume eggs of the six-lined racerunner, *Cnemidophorus sexlineatus* (Linnaeus) within artificially prepared nests (Mount 1981). Freed and Neitman (1988) observed RIFA to prey upon newly metamorphosed Houston toads (*Bufo houstonensis* Sanders) as they emerged from water.

Direct impacts of RIFA on herpetofauna are documented, but indirect impacts may be more difficult to assess (Allen et al. 2004). RIFA are believed to be the primary cause of the extirpation of Texas horned lizards *Phrynosoma cornutum* (Harlan) from parts of its geographic range (Gibbons et al. 2000). RIFA indirectly, negatively affect Texas horned lizards through competition with harvester ants (*Pogonomrymex* spp.), the lizard's main prey (Donaldson et al. 1994, Webb and Henke 2003). Horned lizards rarely eat fire ants while their main food source is harvester ants.

RIFA's range now completely overlaps that of American alligators, *Alligator mississippiensis* (Daudin). Alligator nests provide a source of disturbance and appropriate habitat for fire ant nests in areas that might otherwise be saturated with water (Allen et al. 1997). Surveys conducted by Allen et al. (1997) around central Florida lakes indicate that up to 20% of alligator nests in marsh habitat contain RIFA. During pipping stage of alligator hatch, alligators that were stung showed a two gram decrease in body mass compared with those alligators not stung by RIFA (Allen et al. 1997). Reagan et al. (2000) reported a 14.6% loss in alligator hatchlings due to RIFA and concluded that RIFA may affect the willingness of adult alligators to open the nest when the young hatch.

To assess the impact RIFA may pose on herpetofaunal communities in pine-dominated forests in Louisiana, a pitfall array was used to monitor herpetofaunal number in response to RIFA suppression at Alexander State Forest and Sandy Hollow WMA.

Methods

<u>Herpetofaunal Sampling</u>

Sampling occurred from May to August and January/February for four consecutive years on each 2.02 ha plot within both forests. Herpetofauna were trapped for three consecutive nights using pitfall traps that consisted of 25.40 cm (10 inch) diameter PVC pipe buried 0.3 m (1 ft) into the ground flush with the soil surface. The bottom of the PVC pipe was covered with screen wire before burial to allow drainage and avoid animal escape underneath. Each trap array consisted of three pitfall traps placed 4.57 m (15 ft) apart with two pieces of aluminum flashing 4.57 m (15 ft) long and 25.40 cm (10 inches) tall buried vertically in the soil connecting the pitfalls in a line. The aluminum flashing guided individuals into one of three pitfalls. To protect captured herpetofauna from rain and heat, cover boards made of 20.32 x 20.32 cm (8 x 8 inch) plywood with 2.54 cm (1 inch) legs served as a cover for each pitfall. To further increase the rate of capture, two funnel traps were placed along each side of two pieces of metal flashing (four funnels per array). Funnel traps consisted of a cylinder rolled from a 71.12 cm x 60.96 cm (28 in. x 24 in.) piece of 0.3175 cm (1/8 inch) aluminum mesh wire; with one fixed and one removable funnel [made from a 30.48 cm x 30.48 cm (12 in. x 12 in.) piece of screen wire] attached into separate ends of each cylinder. Each pair of funnels placed along the side of the flashing was covered with a pair of 60.96 cm x 60.96 cm (2 ft. x 2 ft.) pieces of plywood secured at the edge to form a tent-like shelter for protection of captured herpetofauna. Figure 4.1 depicts the herpetofauna traps assembled in the field.

Three herpetofaunal pitfall trap arrays were on each treated and untreated-control plot within each forest. The three arrays were placed diagonally across the small mammal grid starting at the top left corner and ending at the bottom right corner. Herpetofauna (except snakes – which were rarely captured) were weighed with a Pesola® spring balance, measured, marked using the toe clip method described by Heyer et al. (1994) and released. Total length and snout-vent length were recorded in millimeters (Heyer et al. 1994).

Statistical Analysis

Due to low sample sizes statistical analysis were not conducted on all possible herpetofaunal and RIFA interactions at each field site. Chi-square analyses, using SAS version 9.1, were conducted between years and period for individual species that made up the majority of the captures at each field site (SAS Institute Inc. 2002). Statistical significance was determined

Figure 4.1. Herpetofauna pitfall trap, showing aluminum flashing, funnels covered with plywood tents and one of three pits covered with a plywood cover.

at $\alpha = 0.05$. Observations from the four years of sampling data were made on the remaining capture and recapture data.

Results

Alexander State Forest

After four years of sampling, eight herpetofaunal species were captured at Alexander State Forest (Table 4.1). Captures obtained from pitfalls consisted of 28 individual captures and two recaptures. At Alexander State Forest ground skinks, *Scincella lateralis* (Say) made up the majority (53.5%) of the captures with 15 individuals captured during the study. During period A (pre-treatment year) three ground skinks were captured on untreated-control plots and two on treated plots which was not significantly different ($\chi^2 = 0.2$, df = 1, P = 0.65, Table 4.2). For two consecutive post-treatment years (period B), one ground skink was captured on untreated-control plots and one on treated plots during both 2003 and 2004; thus no significant difference was detected untreated-control and treated plots ($\chi^2 = 1.0$, df = 1, P = 1.00, Table 4.2). In 2005 one ground skink was captured on the untreated-control plots and five from the treated plots, but no significant difference was detected between untreated-control and treated plots ($\chi^2 = 2.67$, df = 1, P = 0.10, Table 4.2). Overall ground skink captures on untreated-control and treated plots were not significantly different between periods A ($\chi^2 = 0.0$, df = 1, P = 1.0) or B ($\chi^2 = 2.78$, df = 1, P = 0.10). No ground skinks were recaptured through the course of the study.

Excluding ground skinks, observations were made on remaining herpetofaunal captures and recaptures due to low sample sizes. During period A, one squirrel tree frog was captured from treated plots at Alexander State Forest. During period B, five species were captured on treated plots; one green anole, one five-lined skink, one gulf coast toad, and one six-lined racerunner. On untreated-control plots, captures during period B consisted of three broadheaded skinks, one eastern narrow mouth toad, two five-lined skinks and two gulf coast toads. No individuals were recaptured during period A at Alexander State Forest, although in period B a gulf coast toad from a treated plot and a five-lined skink from an untreated-control plot were recaptured in May 2004 and 2005, respectively.

<u>Sandy Hollow WMA</u>

At Sandy Hollow WMA, nine species were captured over four years of sampling (Table 4.3). Captures obtained from pitfalls consisted of 39 individual captures and six recaptures. Southeastern five-lined skinks (*Eumeces inexpectatus* Taylor) made up the majority (48.7%) of the captures at Sandy Hollow WMA with nineteen individual captures. During 2002 (period A) and 2003 (year one of period B) no southeastern five-lined skinks were captured on untreated-control or treated plots and were not significantly different ($\chi^2 = 0.0$, df = 1, P = 1.0, Table 4.4). In 2004, fifteen southeastern five-lined skinks were captured on treated plots with none captured on untreated-control plots, and so were significantly higher on treated plots ($\chi^2 = 14.97$, df = 1, P = 0.0001, Table 4.4). Similarly, the following year (2005) again no southeastern five-lined skinks

Table 4.1. Herpetofaunal species captured at Alexander State Forest on untreated-control and treated plots with percent of total captured for individual species.

Species Captured	Common Name	Total Captured Untreated-Control	Total Captured Treated	Percent of Total Captured
Anolis carolinensis Voigt	Green Anole	0	1	3.6%
Eumeces laticeps (Schneider)	Broadheaded Skink	3	0	10.7%
Eumeces fasiatus (Linnaeus)	Five-lined Skink	2	1	10.7%
Scincella lateralis	Ground Skink	6	9	53.5%
Cnemidophorus sexlineatus	Six-lined Racerunner	0	1	3.6%
Gastrophryne carolinensis (Holbrook)	Eastern Narrow Mouth Toad	1	0	3.6%
Bufo valliceps Wiegmann	Gulf Coast Toad	2	1	10.7%
Hyla squirella (Bosc)	Squirrel Tree Frog	0	1	3.6%

Table 4.2. Comparisons of ground skink captures between untreated-control and treated plots for each year at Alexander State Forest.

Year	Untreated-Control Frequency	Treated Frequency	χ^2	P-value
2002	3	2	0.20	0.65
2003	1	1	0.00	1.00
2004	1	1	0.00	1.00
2005	1	5	2.67	0.10

Table 4.3. Herpetofaunal species captured at Sandy Hollow WMA on untreated-control and treated plots with percent of total captured for individual species.

Species Captured	Common Name	Total Captured Untreated-Control	Total Captured Treated	Percent of Total Captured
Anolis carolinensis	Green Anole	0	1	2.6%
Eumeces laticeps	Broadheaded Skink	0	2	5.1%
Eumeces inexpectatus	Southeastern Five-lined Skink	3	16	48.7%
Scincella lateralis	Ground Skink	2	2	10.3%
Sceloporus undulates (Bosc and Daudin)	Eastern Fence Lizard	1	1	5.1%
Gastrophryne carolinensis	Eastern Narrow Mouth Toad	2	3	12.8%
Bufo fowleri Hinckley	Fowler's Toad	0	1	2.6%
Bufo quercicus Holbrook	Oak Toad	1	1	5.1%
Bufo valliceps	Gulf Coast Toad	1	2	7.7%

were captured on untreated-control plots while three were captured on treated plots, but were not significantly different ($\chi^2 = 2.97$, df = 1, P = 0.08, Table 4.4). Overall, southeastern five-lined skink captures on untreated-control and treated plots were not significantly different during period A ($\chi^2 = 0.01$, df = 1, P = 0.92, Table 4.4), while captures were significantly higher on treated plots compared with untreated-control plots during period B ($\chi^2 = 17.98$, df = 1, P < 0.0001, Table 4.4). Three southeastern five-lined skinks were recaptured on treated plots during 2004.

Excluding southeastern five-lined skinks, during period A (pre-treatment) two toads were

Table 4.4. Comparisons of southeastern five-lined skinks captures between untreated-control and treated plots for each year at Sandy Hollow WMA.

Year	Untreated-Control Frequency	Treated Frequency	X^2	P-value
2002	0	0	0.00	1.00
2003	0	0	0.00	1.00
2004	0	15	11.97	0.0005
2005	0	3	2.97	0.08

captured, an eastern narrow mouth toad and an oak toad, both on treated plots. Species captured during period B on treated plots consisted of two broadheaded skinks, two ground skinks, one eastern fence lizard, one green anole, two eastern narrow mouth toads, one fowler's toad, and two gulf coast toads. Captures on untreated-control plots during period B consisted of one eastern fence lizard, two ground skinks, two eastern narrow mouth toads, one gulf coast toad, and one oak toad. No individuals were recaptured during period A at Sandy Hollow WMA. Recaptures during period B consisted of an eastern fence lizard recaptured from a treated plot in July 2004, and an oak toad recaptured on an untreated-control plot in August 2004.

Discussion

Ground skinks and southeastern five-lined skinks made up the majority of the captures at Alexander State Forest and Sandy Hollow WMA, respectively. Both of these species are excellent candidates for assessing the impacts of RIFA on herpetofaunal communities. Ground skinks have a relatively short life span in which they are primarily ground-dwelling and inhabit forest litter where they forage for small insects and spiders (Brooks 1967). The southeastern five-lined skink is also primarily ground-dwelling and has been shown to inhabit all terrestrial habitats in Florida (Mushinsky 1992). However, Mushinsky (1992) showed the southeastern five-lined skink to be more adapted to drier, more open habitats than its two congeners (*Eumeces fasciatus* and *E. laticeps*) where their ranges are broadly sympatric. The ranges of ground skinks and southeastern five-lined skinks overlap the range of RIFA in Louisiana. RIFA and ground skinks have been documented from every parish in Louisiana; the southeastern five-lined skink is confined to a portion of southeast Louisiana known as the Florida parishes (Dundee and Rossman 1989), characterized by dry sandy soils and more open pine-dominated habitat where RIFA flourish (Callcott and Collins 1996).

Sample sizes for ground skinks at Alexander State Forest and southeastern five-lined skinks at Sandy Hollow WMA were very low compared with other published studies in similar habitats. Brooks (1967) hand-captured ground skinks on a 0.51 ha (1.25 acre) plot in Florida and estimated population densities to be a maximum of 263 and a minimum of 131 per 0.4 ha (1 acre). Turner (1960) measured average population density for ground skinks in southeast Louisiana. The size of his study area was not discussed, but approximation of the area based on Figure 1 in his papers yields an average of 175 hand-captured ground skinks per 0.152 ha (0.38 acre). Mushinsky (1960), during a study in a longleaf-pine system in Florida, found pitfall trap capture rates of southeastern five-lined skinks to range from 22-70 per 1.5 ha (3.7 acres) depending on life stage and burn regime within the system.

Herpetofaunal capture rate was low throughout this study. However observations made from capture data reveal possible impacts of RIFA on ground skinks and southeastern five-lined skinks. At Alexander State Forest, ground skinks showed a 33% decrease on untreated-control plots and a 40% increase on treated plots following two years of fire ant suppression (Table 4.1). Similar results were found for southeastern five-lined skinks at Sandy Hollow WMA. Southeastern five-lined skinks were never captured on untreated control plots throughout the study, but following a year of treatment twelve individuals were captured on treated plots and then another three the consecutive year (Table 4.2). This indicates that RIFA may impact these two species throughout their range in Louisiana and that RIFA suppression may enable these two species to rebound following one to two years of RIFA suppression.

Due to low sample sizes obtained throughout this study RIFA's impacts on herpetofaunal communities in Louisiana are unclear. Possible reasons for low sample sizes could be sampling effort and technique, as well as generally low populations of herpetofauna at both field sites. Species of interest should be another consideration when pitfall sampling herpetofauna; some herpetofaunal species have better jumping and climbing abilities than others (Heyer et al. 1994) which should be accounted for in the trapping technique. Two of the eleven species captured in this study, the green anole and the squirrel tree frog, may have biased sampling due to their ability to enter and leave traps at will. To adequately assess impacts of RIFA on native herpetofaunal communities, further research needs to be conducted with a more narrow focus using genus- or species-specific trapping techniques with sufficient traps per unit land area, and samples administered as frequently as possible. RIFA suppression (see chapter 2) on a landscape level may benefit land and habitat managers who are concerned with the recent global decline of herpetofaunal species (Gibbons et al. 2000) or managing endangered species within areas RIFA infested areas.

Chapter 5.

Impacts of Red Imported Fire Ants on Native Ground-dwelling Invertebrate Communities in Longleaf-pine and Pine-hardwood Forests

Introduction

RIFA may pose a substantial threat to the biodiversity of native arthropod communities (Porter and Savignano 1990). They are voracious, omnivorous foragers; they consume almost any type of animal or plant material. Generally, RIFA feed on other insects, which they locate, sting to paralyze and consume (Vinson and Sorensen 1986). They will prey on ticks, larvae of multiple species of insects, ground-inhabiting insects, and worms (Vinson and Sorensen 1986). In multiple studies, RIFA is assumed to account for the largest mortality factor of the lonestar tick, *Amblyomma americanum* (Linnaeus), preying upon all life stages (Fleetwood et al. 1984, Burns and Melancon 1977, Harris and Burns 1972). RIFA has also been observed preying on eggs of striped earwigs, *Labidura riparia* (Pallas), apple snails, *Pomacea paludosa* (Say), bee larvae (*Megachile integra* Cresson), horn flies, *Haematobia irritans* (Linaeus), the endangered Schaus swallowtail butterfly (*Papilio aristodemus ponceanus* Schaus), and some coprophagous scarabs (Gross and Spink 1969, Stevens et al. 1999, Williams et al. 1986, Forys et al. 2001, Summerlin et al. 1984). Vinson (1990) showed that fruit traps placed in areas exposed to RIFA would trap fewer decomposer arthropods, which indicates decreased abundance and diversity than normally present when RIFA are excluded. These include adults and immatures from insect families: Nitidulidae and Tephritidae, adult Staphylinidae, several families of parasitic Hymenoptera, and several genera of ants other than *Solenopsis*. Hu and Frank (1996) showed a significant increase (62.9 and 94.3%) in the numbers of dung-inhabiting arthropods within sites treated with Amdro® for RIFA. Porter and Savignano (1990) also found a decrease in overall species richness of arthropods when exposed to RIFA. Species richness of non-ant arthropods was 30% lower and individual numbers were 75% lower in infested sites (Porter and Savignano 1990). Recently, Morrison and Porter (2003) refute this and believe that native arthropod communities may be more resistant or resilient than generally believed.

Some entomologists consider RIFA to be beneficial because the ants may help control populations of harmful arthropods such as crop pests and arthropods that are nuisances to humans (Burns and Melancon 1977). Lee et al. (1994) documented RIFA as a potential aid in mosquito control. RIFA preyed on the mosquito, *Psorophora columbiae* (Dyar and Knab), eggs in both laboratory and field settings (Lee et al. 1994). Its value as a predator to crop pests such as boll weevils, bollworms, and tobacco budworms makes RIFA an important component in cotton ecosystems (Sterling 1978, Sterling et al. 1979, McDaniel and Sterling 1982). Hensley et al. (1961) documented significantly higher numbers of sugarcane borers, *Diatraea saccharalis* (Fabricius) after Louisiana sugarcane fields were treated with heptachlor for RIFA control. He found 62% of the sampled sugarcane on treated plots to be affected by the borer, compared with 42% on untreated-control plots (Hensley et al. 1961). Damage by the sugarcane borer increased 53% and 69% following the application of Mirex® for control of RIFA (Reagan et al. 1972). Breene (1991) states that cotton growers can control cotton pests using minimal or no insecticides if they are willing to work with RIFA.

RIFA can also negatively impact beneficial arthropods in an agricultural setting. Eubanks et al. (2002) observed that RIFA reduce survival of ladybird beetles (*Coccinella septempunctata* Linnaeus and *Hippodamia convergens* Guèrin-Mèneville) by 50% and green lacewing larvae, *Chrysoperla carnea* (Stephens) by 38% in a greenhouse experiment. He also documented that the densities of ladybird beetles, spiders, and big-eyed bugs were significantly higher in field experiments with suppressed fire ant populations (Eubanks et al. 2002). Harris et al. (2003)

supported these findings, documenting a decrease in green lacewing larvae and pupae as well as a decrease in adult ladybird beetles, in a Texas pecan orchard.

To assess the impact RIFA pose on ground-dwelling invertebrate communities in Louisiana, a pitfall array was used to monitor invertebrate numbers in response to RIFA suppression at Alexander State Forest and Sandy Hollow WMA.

Methods

Insect Sampling

Sampling occurred for two nights, every three months beginning in February 2002 on each treated and untreated-control plot for four consecutive years. Prior to RIFA suppression (period A, see chapter 2) five samples were collected at Alexander State Forest and Sandy Hollow WMA in February, May, and August 2002 and January and March 2003. Post-treatment (period B) samples at both field sites were collected in May, August, and December 2003; March, June, and August 2004; and January, March, May, August, and December 2005. Three insect pitfall trap arrays were present on each treated and untreated-control plot; which were positioned diagonally across the small mammal grid from the top right corner to the bottom left corner (opposite herpetofaunal pitfall arrays). Figure 5.1 depicts the invertebrate pitfall traps assembled in the field. Traps consisted of a paired, pitfall design with a 1.83 m (6 ft.) long piece of aluminum flashing placed vertically in the soil to guide insects into pitfalls. At each end of the aluminum flashing, a 400-ml tri-corner beaker was buried flush with the soil surface. A 250-ml collection beaker (with the rim trimmed) filled with Prestone® LoTox Antifreeze was placed within the tri-corner beaker to collect samples (Hooper-Bùi and Pranschke 2006). Insects trapped in antifreeze were brought back to the lab, sorted to order, counted, properly labeled, and preserved in 95% alcohol.

Figure 5.1. Invertebrate pitfall trap with vertical aluminum flashing and the two pitfalls on each end of the flashing.

Statistical Analysis

SAS version 9.1 software package was used to assess the impacts RIFA pose on ground-dwelling invertebrate communities in two pine-dominated ecosystems in Louisiana (SAS Institute Inc. 2002). Proc Mixed was used within SAS to detect significant differences in mean number of ground-dwelling invertebrates (within orders collected) between untreated-control and treated paired plots for each sampling period within each of the four years. For each sampling date, samples from the three pitfall trap arrays from each plot were pooled. From the pooled samples the mean number of individuals was analyzed within each order between untreated-control and treated paired plots (plot = replicate). Orders of invertebrates were only analyzed if >150 specimens were collected throughout the experiment. Appendix C and D shows all orders captured and number of specimens collected within each order at Alexander State Forest and Sandy Hollow WMA, respectively. RIFA were not removed from pitfall samples and were included in analyses of order Hymenoptera. Period A (pre-treatment) was used as a covariate within Period B (post-treatment) analysis's. Statistical significance was determined at $\alpha = 0.05$.

Results

Alexander State Forest

More than 150 specimens were collected from seven orders at Alexander State Forest: Araneae, Acari, Collembola, Orthoptera, Coleoptera, Hymenoptera, and Diptera (Appendix C). Hymenoptera was the only order to show a significantly higher mean number of individuals on treated plots (19.07 ± 5.19, Mean ± SE) compared with untreated-control plots (11.87 ± 2.71) during period A ($F_{4,16} = 6.33$, P = 0.003). Table 5.1 lists all other orders collected during period A, detecting no significant difference in mean numbers of individuals between untreated-control and treated plots.

Table 5.1. Comparisons of mean number of individuals for invertebrate orders, during period A, at Alexander State Forest on untreated-control and treated plots.

Order	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	4	18	2.90 ± 0.33	2.96 ± 0.38	0.43	0.79
Acari	4	18	1.29 ± 0.24	0.89 ± 0.20	0.08	0.99
Collembola	4	20	23.38 ± 2.61	28.78 ± 3.44	1.65	0.20
Orthoptera	4	20	0.49 ± 0.14	0.69 ± 0.18	1.21	0.34
Coleoptera	4	18	1.47 ± 0.27	1.04 ± 0.17	0.23	0.92
Diptera	4	20	0.80 ± 0.26	0.82 ± 0.29	0.14	0.97

During 2003, (first year of period B) no significant difference was detected in mean number of ground-dwelling invertebrates, within all orders analyzed, between untreated-control and treated plots (Table 5.2).

Table 5.2. Comparisons of mean number of individuals for invertebrate orders, during 2003, at Alexander State Forest on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	2	11	4.56 ± 0.59	4.07 ± 0.72	1.49	0.27
Acari	2	8.75	1.22 ± 0.26	0.52 ± 0.18	0.90	0.44
Collembola	2	11	19.67 ± 2.54	23.19 ± 4.21	0.33	0.72
Orthoptera	2	9.37	0.74 ± 0.45	1.04 ± 0.33	0.68	0.53
Coleoptera	2	9.63	1.22 ± 0.38	1.48 ± 0.33	1.85	0.21
Hymenoptera	2	11	11.48 ± 5.00	11.41 ± 2.62	0.30	0.74
Diptera	2	11	2.81 ± 2.17	0.67 ± 0.15	2.13	0.17

Orthoptera samples, in 2004, showed a significantly higher mean number of individuals on untreated-control plots (1.25 ± 0.32) compared with treated plots (0.29 ± 0.16, $F_{2,8}$ =5.90, P = 0.03). Table 5.3 shows all other orders collected in 2004 with no significant differences between untreated-control and treated plots.

No significant differences, within orders, were found in mean number of ground-dwelling invertebrates between untreated-control and treated plots again in 2005 (Table 5.4).

Sandy Hollow WMA

More than 150 specimens were collected from nine orders at Sandy Hollow WMA: Araneae, Acari, Diplopoda, Collembola, Orthoptera, Hemiptera, Coleoptera, Hymenoptera, and Diptera (Appendix D). During period A, Acari samples showed a significantly higher mean number of individuals on untreated-control plots (2.04 ± 1.07) compared with treated plots (0.47

± 0.13, $F_{4,16}$ = 6.13, P = 0.003). Table 5.5 shows all orders analyzed in period A with no significant differences between untreated-control and treated plots.

Table 5.3. Comparisons of mean number of individuals for invertebrate orders, during 2004, at Alexander State Forest on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	2	9.28	3.74 ± 0.59	5.96 ± 1.41	3.48	0.07
Acari	2	11	2.37 ± 0.50	1.11 ± 0.36	0.05	0.95
Collembola	2	9.23	64.15 ± 12.0	70.93 ± 18.66	0.16	0.86
Coleoptera	2	8	2.81 ± 0.50	3.63 ± 0.74	2.24	0.17
Hymenoptera	2	8.55	5.41 ± 1.70	20.11 ± 3.04	2.97	0.10
Diptera	2	9.25	3.96 ± 0.74	4.41 ± 1.06	0.16	0.85

Table 5.4. Comparisons of mean number of individuals for invertebrate orders, during 2005, at Alexander State Forest on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	4	16.7	2.53 ± 0.34	3.60 ± 0.64	0.70	0.60
Acari	4	16	1.20 ± 0.29	0.64 ± 0.14	0.68	0.61
Collembola	4	19	26.53 ± 3.09	36.64 ± 8.73	0.42	0.80
Orthoptera	4	16.5	0.38 ± 0.14	0.53 ± 0.16	0.61	0.66
Coleoptera	4	16	3.27 ± 0.54	3.73 ± 0.80	0.58	0.68
Hymenoptera	4	19	4.82 ± 0.86	10.78 ± 2.04	2.41	0.09
Diptera	4	17.3	1.71 ± 0.37	2.27 ± 0.40	0.02	0.89

Coleoptera samples in 2003, showed a significantly higher mean number of individuals on treated plots (3.41 ± 0.58) compared with untreated-control plots (3.19 ± 0.65, $F_{2,11} = 4.79$, $P = 0.03$). Table 5.6 shows all orders collected in 2003 with no significant differences between untreated-control and treated plots.

During 2004 mean number of Hymenoptera were found to be significantly higher on untreated-control plots (39.17 ± 9.21) compared with treated-plots (4.81 ± 0.92, $F_{3,15} = 12.38$, $P = 0.0002$). Table 5.7 shows all orders collected in 2004 with no significant differences between untreated-control and treated plots.

Significantly higher mean numbers of Collembola were detected on untreated-control plots (69.03 ± 20.84) compared with treated plots (46.67 ± 6.73) in 2005 ($F_{3,15} = 8.41$, $P = 0.0016$). Table 5.8 shows all orders collected in 2005 with no significant differences between untreated-control and treated plots.

Table 5.5. Comparisons of mean number of individuals for invertebrate orders, during period A, at Sandy Hollow WMA on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	4	20	2.89 ± 0.29	2.11 ± 0.30	1.58	0.22
Diplopoda	4	16	0.24 ± 0.10	0.82 ± 0.40	0.22	0.93
Collembola	4	18	14.80 ± 2.69	13.51 ± 1.83	1.58	0.22
Orthoptera	4	16	1.16 ± 0.25	1.58 ± 0.30	0.55	0.70
Hemiptera	4	16	0.64 ± 0.16	1.58 ± 0.30	1.99	0.15
Coleoptera	4	18	1.09 ± 0.22	1.56 ± 0.35	1.12	0.38
Hymenoptera	4	18	27.49 ± 6.88	27.56 ± 9.49	0.68	0.62
Diptera	4	16	1.07 ± 0.22	0.76 ± 0.15	2.62	0.07

Table 5.6. Comparisons of mean number of individuals for invertebrate orders, during 2003, at Sandy Hollow WMA on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	2	11	4.70 ± 0.96	4.30 ± 0.91	0.60	0.56
Acari	2	8.73	1.15 ± 0.38	0.67 ± 0.32	0.37	0.70
Diplopoda	2	8	0.78 ± 0.39	0.19 ± 0.09	0.33	0.73
Collembola	2	8	12.89 ± 1.80	15.0 ± 3.66	2.91	0.11
Orthoptera	2	11	2.41 ± 0.50	4.07 ± 0.73	0.69	0.52
Hemiptera	2	8	2.30 ± 0.41	1.96 ± 0.30	0.65	0.55
Hymenoptera	2	8	18.48 ± 5.19	51.04 ± 17.38	0.61	0.57
Diptera	2	9.18	2.11 ± 0.37	2.0 ± 0.40	3.86	0.06

Table 5.7. Comparisons of mean number of individuals for invertebrate orders, during 2004, at Sandy Hollow WMA on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	3	15	2.75 ± 0.28	2.39 ± 0.38	2.10	0.14
Acari	3	12	0.56 ± 0.17	0.44 ± 0.12	1.34	0.31
Diplopoda	3	15	1.11 ± 0.33	1.14 ± 0.58	0.21	0.89
Collembola	3	15	19.78 ± 2.08	18.61 ± 1.65	0.22	0.88
Orthoptera	3	15	1.23 ± 0.31	1.56 ± 0.61	1.42	0.27
Hemiptera	3	13.3	0.58 ± 0.14	0.56 ± 0.15	0.73	0.55
Coleoptera	3	12	4.47 ± 2.13	1.89 ± 0.31	1.91	0.18
Diptera	3	13.5	1.72 ± 0.29	1.44 ± 0.30	0.54	0.66

Table 5.8. Comparisons of mean number of individuals for invertebrate orders, during 2005, at Sandy Hollow WMA on untreated-control and treated plots.

Date	Num DF	Den DF	Treated Mean ± SE	Untreated-Control Mean ± SE	F Value	P Value
Araneae	3	12.7	4.03 ± 1.01	5.08 ± 0.79	0.22	0.88
Acari	3	15	0.44 ± 0.13	0.75 ± 0.21	2.45	0.10
Diplopoda	3	12	0.25 ± 0.10	0.39 ± 0.17	1.12	0.38
Orthoptera	3	13.2	1.14 ± 0.39	2.19 ± 0.33	0.97	0.43
Hemiptera	3	13.1	0.61 ± 0.12	0.92 ± 0.23	0.77	0.53
Coleoptera	3	12	8.83 ± 1.06	7.47 ± 0.74	0.02	1.00
Hymenoptera	3	12	20.0 ± 5.69	60.61 ± 14.06	1.77	0.21
Diptera	3	13.3	4.25 ± 0.62	3.53 ± 0.53	1.75	0.20

Discussion

Porter and Savignano (1990) suggested RIFA may pose a substantial threat to biodiversity of native arthropod communities. However, negative impacts may only occur for the first few years following initial invasion of RIFA (Morrison 2002). After 10-12 years RIFA may no longer pose negative impacts to native arthropod communities, and diversity and abundance of native arthropods may exceed pre-invasion levels (Morrison 2002). Following their initial impact on communities and adaptation of native arthropod communities to RIFA presence, both RIFA and arthropod communities may then be regulated by common factors (e.g. productivity, Morrison and Porter 2003). Results presented here support these latter two findings (Morrison 2002, Morrison and Porter 2003) and suggest that RIFA have minimal impacts on ground-dwelling invertebrates within two pine-dominated ecosystems in Louisiana.

Seventeen orders were collected at Alexander State Forest, seven had sufficient numbers for analyses. In 2002 (pre-treatment), 2003, and 2005 (both post-treatment), no significant difference in mean abundances of ground-dwelling arthropods were detected between untreated-control and treated plots. Field sites in published studies by Porter and Savignano (1990), Morrison (2002), Morrison and Porter (2003), and Galarraga (2003) on the impacts of RIFA on invertebrate communities, all have been conducted in pastures, cotton fields, or grassy fields juxtaposed to wooded areas. However, Alexander State Forest consists of a semi-closed canopy with a dense mid- and under-story. This type of ecosystem may provide RIFA, a generalist predator, with a wide range of food availability thereby spreading risks across multiple species of invertebrates minimizing the impacts RIFA pose on native ground-dwelling invertebrates.

In 2004 only one order, Orthoptera, (grasshoppers, crickets, and katydids) showed a significant difference between untreated-control and treated plots at Alexander State Forest. Surprisingly, mean numbers of Orthoptera or grasshoppers and crickets were higher on untreated-control plots (1.00 ± 0.26) compared with treated plots (0.22 ± 0.12). This suggests that RIFA pose minimal impacts on Orthoptera communities and that Orthoptera are regulated by some other factor than RIFA. This finding is supported by Gallarraga (2003), who also showed, in a study in Texas, that Orthoptera were captured in pitfalls in higher mean abundance on plots with RIFA compared with plots where RIFA were suppressed with Amdro® and Extinguish®. Wilson and Oliver (1969) measured food habits of RIFA in a field study in southeast Louisiana and found that no identifiable adult or immature Orthoptera were part of RIFA's foraging diet; although Orthoptera eggs made up 0.13% of the foraging diet.

Nineteen orders were collected from pitfall samples at Sandy Hollow WMA, nine of which were analyzed. During period A (2002, pre-treatment) Acari or mites and ticks showed a significantly higher mean number of individuals on untreated-control plots (2.04 ± 1.07) compared with treated plots (0.47 ± 0.13). Since period A was used as a covariate within the model, mean number of Acari for period B analyses were corrected for the difference in mean number of Acari captured in period A. RIFA do not appear to be the regulating factor in Acari populations.

In 2003 following RIFA suppression (see Chapter 2), Coleoptera (beetles) was the only order found to be significantly different between untreated-control and treated plots. Mean numbers of Coleoptera were found to be higher on treated plots (3.41 ± 0.58) compared with untreated-control plots (3.19 ± 0.65). Since this finding was not present again in 2004 or 2005, or for any other order, RIFA were unlikely to be the cause of this difference. Work by Porter and Savignano (1990) support this argument as they found no significant difference in mean number of individuals and species within Coleoptera, between plots pre- and post-invasion by RIFA.

During 2004, Hymenoptera (wasps, bees, and ants with RIFA included) was the only order to show a significant difference between untreated-control and treated plots. Mean number of Hymenoptera were significantly higher on untreated-control plots (39.17 ± 9.21) compared with treated plots (4.81 ± 0.92). Since RIFA numbers were not removed from invertebrate pitfall sample data before analysis, higher numbers of Hymenoptera on untreated-control plots are not surprising. This also coincides with a significantly higher mean number of RIFA on untreated-control plots compared with treated plots (97% difference) following the start of evening Amdro® treatments at Sandy Hollow WMA (see Chapter 2). However, this finding is not present in the two other treatment years (2003 and 2005). Results of RIFA from pitfall traps in 2004 and results from baited vials presented in Chapter 2 indicate that pitfall traps may not be the best measure of RIFA's abundance in an ecosystem. Thus, RIFA's impact on ground-dwelling invertebrate communities may not be detectable from pitfall samples.

In 2005, Collembola (springtails) was the only order that showed a significant difference between untreated-control and treated plots at Sandy Hollow WMA. Surprisingly, mean numbers of Collembola were found to be significantly higher on untreated-control plots (69.03 ± 20.84) compared with treated plots (46.67 ± 6.73). Similar to Orthoptera at Alexander State Forest this finding suggests that RIFA may pose light impact to Collembola at Sandy Hollow WMA and that other factors are regulating Collembola communities. These findings agree with Galarraga (2003) who also found higher mean number of Collembola on plots with RIFA present as opposed to plots in which RIFA had been suppressed. However, this contradicts Wilson and Oliver (1969) in which Collembola made up the highest percentage (12.9%) of the identifiable foraging diet of RIFA in southeast Louisiana.

As opposed to Alexander State Forest, Sandy Hollow WMA is a continuously disturbed, open ecosystem, in which RIFA thrive. Sandy Hollow WMA is composed of an essentially open canopy with little to no mid- or under- story. This type of ecosystem is similar to field sites used in a majority of published literature on RIFA and invertebrate community interactions. Field sites like cotton fields (Galarraga 2003), pastures (Morrison 2003), and wooded areas juxtaposed to grassy fields (Porter and Savignano 1990 and Morrison 2002), are all similar to Sandy Hollow WMA in that they are all ecosystems shaped by disturbance. Ground-dwelling invertebrate abundance was lower in this study, in comparison to these other experiments. For example, Porter and Savignano (1990), whose study used similar methods of measuring RIFA's impact on invertebrates in Texas, showed 32-96% higher invertebrate capture rate on plots not infested with RIFA and 4-90% higher capture rate on infested sites in all relevant orders. However, significant differences within invertebrate orders found in Porter and Savignano (1990) are comparable to what was found at both Alexander State Forest and Sandy Hollow WMA.

Based on these results, RIFA pose minimal impacts on native ground-dwelling arthropod communities within two pine-dominated ecosystems in Louisiana; and other factors besides RIFA predation are regulating these communities. However, some discretion should be used in interpreting ecological results where ordinal level classification is used. Unless an author is looking at differences among species, all levels of classification are arbitrary. Orders presented here contain multiple species with many unique and diverse life histories in which RIFA may impact, but would not be obvious when observing differences at ordinal taxonomic levels. In an attempt alleviate some of the arbitrary nature of ordinal level classification within this study, Lycosidae (wolf spiders) were extracted from the pitfall samples and identified to species. Chapter 6 will discuss differences within Lycosidae as a family, and among Lycosidae genera and species with respect to RIFA suppression.

Chapter 6.

Impacts of Red Imported Fire Ants on Wolf Spiders (Araneae: Lycosidae) Communities in Longleaf-pine and Pine-hardwood Forests

Introduction

Spiders, order Araneae, are one of the most diverse groups in the world with over 30,000 described species (Kaston 1978), yet little research has been conducted on impacts RIFA pose on this faunal taxon. Eubanks et al. (2002) observed a significantly higher number of spiders in an agricultural setting after RIFA populations were suppressed. The literature lacks ecological data on the impact RIFA inflict on spiders.

Spiders are preyed upon by small mammals, birds, herpetofauna, RIFA and other invertebrates, which make them ideal candidates for an ecological-based study. Many grassland bird species are granivorous, but become largely insectivorous during breeding season, and nestlings of these species are usually fed a protein rich diet of arthropods including spiders, beetles, Orthopterans, and Lepidopterans (McIntyre and Thompson 2003). Much attention has been focused on the Red-cockaded Woodpecker, *Picoides borealis* (Vieillot), since it was listed as endangered in 1970 (Jordan and Sanders 2002). The decline of the Red-cockaded Woodpecker (RCW) by 99% of its original numbers is due to 97% loss of longleaf pine ecosystem from commercial harvest, naval stores/turpentine industry and more recently commercial tree farming, urbanization and agriculture (Jordan and Sanders 2002). Many studies have looked at the diets of these birds, both in adults and nestlings, to gain further insight into what RCWs are feeding on in different habitat types; in every case, spiders make up a portion (4.5-11.4%) of adult's and nestling's diet (Hanula and Engstrom 2000, Hanula et al. 2000, Hess and James 1998).

Spiders are still poorly known in the state of Louisiana, which is probably due to their unattractiveness to humans or the attractiveness of more desirable taxa (Fassbender 2002). Fassbender (2002) completed a study of litter and ground-dwelling spiders in Southeast Louisiana raising the total to 225 described spider species, representing 27 families collected in the state. She asserts that the total described only represents a third to a half of the spiders present (Fassbender 2002).

Spiders in family Lycosidae, commonly known as wolf spiders, comprise approximately 530 species worldwide, occurring on all continents. Yet little is still known about the ecology and life history of some genera (Brown et al. 2003, Vogel 2004). Wolf spiders tend to be drab colored, with spinose legs, and with the posterior row of eyes so strongly curved, it is sometimes mistaken as two rows. Some species make tubular tunnels in the ground or under rocks as sit-and-wait predators, while others never construct a retreat and can be found foraging in grasses, leaf litter, sandy and stony areas as well as various other habitats (Kaston 1978). Wolf spiders are often nocturnal hunters and unlike most spiders, do not use webs to capture prey (Suter and Stratton 2005). They subdue prey items by lunging, grabbing them with their legs, and biting them immediately (Suter and Stratton 2005). Wolf spiders are classified as obligate predators, but have been shown to scavenge on dead arthropods (Knost and Rovner 1975). For example, Knost and Rovner (1975) showed *Lycosa rabida* Walckenaer and *L. punctulata* Hentz prefer scavenging in a laboratory-based experiment (Knost and Rovner 1975).

The egg sacs of females are globular with a seam around the middle referred to as the "equator" (Kaston 1978). Females, except those of genus *Sosippus*, carry the egg sac around attached to her spinnerets (Kaston 1978). Members of genus *Sosippus* are also the only

Lycosidae species that spin webs (Ubick et al. 2005). After emergence, the female's young will climb onto her abdomen and be carried around for a considerable amount of time (Kaston 1978).

Lycosidae were used as a focal invertebrate group from the ground-dwelling invertebrate pitfall samples to assess the impacts RIFA pose on families, genera, and species of wolf spiders.

Methods

From order Araneae, family Lycosidae (wolf spiders) occurred with the greatest number of specimens from four years of sampling data. Lycosidae from pitfall trap samples (described in Chapter 5) were used to contrast effects RIFA pose to invertebrates at family, genus, and species-level classifications rather than ordinal level. Adult male and female Lycosidae were identified to species based on genitalia characters. Male genitalia were removed using minute forceps, identified, and then stored in genitalia vials with the specimen. Female species were able to be identified without removal of genitalia. Males, females, and genitalia were kept covered with 95% ethanol during the identification process to keep specimens from drying out. Identifications were performed using an Olympus® SXZ12 dissecting scope. Upon completion of the project, all invertebrate specimens will be deposited in the Louisiana State Arthropod Museum (LSAM).

Statistical Analysis

SAS version 9.1 software package was used to assess impacts RIFA pose on wolf spider communities in two pine-dominated ecosystems in Louisiana (SAS Institute Inc. 2002). Chi-square analyses were used to test for significant differences in mean number of wolf spiders within family (Lycosidae), as immatures, within genus, and at the species level. Analyses were conducted between untreated-control and treated plots for period A, 2003, 2004, and 2005. Immature spiders are difficult to identify to genus or species, so immatures were also analyzed at the family level. Due to low sample sizes only certain genera and species could be appropriately analyzed. At Alexander State Forest both genera *Schizocosa* and *Pirata*, as well as *Pirata hiteorum* Wallace and Exline and *Schizocosa humilis* (Banks) were collected with sufficient numbers to analyze. At Sandy Hollow WMA genera *Pardosa* and *Pirata*, as well as *Pardosa atlantica* Emerton and *Pirata hiteorum* were analyzed. Statistical significance was determined at $\alpha = 0.05$.

Results

Alexander State Forest

At Alexander State Forest 150 adult Lycosidae were collected throughout the study. During period A, no significant difference was found at the family level in mean number of individuals between untreated-control (2.33 ± 0.67, Mean ± SE) and treated plots (3.00 ± 0.58, $\chi^2_1 = 0.08$, P = 0.77). Additionally, no significant difference in mean number of individuals, in family Lycosidae, was detected in 2003, 2004, and 2005 between untreated-control plots (9.67 ± 3.84, 8.33 ± 2.40, and 7.33 ± 0.67, respectively) compared with treated plots (3.33 ± 3.33, 9.00 ± 5.57, and 7.33 ± 4.67; $\chi^2_1 = 3.09$, P = 0.08, $\chi^2_1 = 0.03$, P = 0.87, and $\chi^2_1 = 0.00$, P = 1.00, respectively).

Immature Lycosidae at Alexander State Forest consisted of 218 collected individuals. The highest number of immature Lycosidae collected in any sampling period was on treated plots in 2003. During period A, no significant difference was found in mean number of immature Lycosidae between untreated-control (10.67 ± 2.33) and treated plots (9.67 ± 2.03, $\chi^2_1 = 0.05$, P = 0.82). Additionally, in 2003, 2004, and 2005 no significant difference in mean number of immatures was detected between untreated-control plots (5.33 ± 1.76, 10.67 ± 5.24, and 9.67 ± 1.45, respectively) compared with treated plots (12.33 ± 2.19, 7.67 ± 2.33, and 6.67 ± 1.20; χ^2_1 = 2.77, P = 0.10, χ^2_1 = 0.49, P = 0.48, and χ^2_1 = 0.55, P = 0.46, respectively).

Seventy-two individuals from genus *Pirata* and 62 individuals from genus *Schizocosa* were collected from Alexander State Forest. Numbers of individual *Pirata* collected ranged from two on treated plots in period A to 26 on treated plots in 2004; while number of individual *Schizocosa* ranged from one on treated plots in 2004 to 13 collected on untreated-control plots in 2005. No significant difference in mean number of individuals in either genus was detected in period A, 2003, 2004, and 2005 (Table 6.1 and 6.2).

Table 6.1. Comparisons on mean number of *Pirata* at Alexander State Forest between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	1.67 ± 0.33	0.67 ± 0.33	0.23	0.63
2003	4.00 ± 1.73	0.00 ± 0.00	2.67	0.10
2004	5.33 ± 2.73	8.67 ± 5.70	0.70	0.40
2005	1.33 ± 0.67	2.33 ± 1.45	0.18	0.67

Table 6.2. Comparisons on mean number of *Schizocosa* at Alexander State Forest between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.67 ± 0.33	2.00 ± 0.58	0.66	0.42
2003	5.00 ± 4.51	2.33 ± 2.33	0.97	0.32
2004	3.00 ± 1.53	0.33 ± 0.33	2.14	0.14
2005	4.33 ± 0.88	2.67 ± 2.67	0.39	0.53

Two species from Alexander State Forest, *Pirata davisi* and *Trabeops aurantiacus* are new records for Louisiana. Fifty-five *Pirata hiteorum* and 45 *Schizocosa humilis* were collected from Alexander State Forest. Similar to genus level classification, no significant difference in mean number of individuals in either species *Pirata hiteorum* or *Schizocosa humilis* was detected in period A, 2003, 2004, and 2005 (Table 6.3 and 6.4). Table 6.5 shows all sixteen species of Lycosidae collected at Alexander State Forest.

Table 6.3. Comparisons on mean number of *Pirata hiteorum* at Alexander State Forest between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	1.67 ± 0.33	0.67 ± 0.33	0.23	0.63
2003	2.33 ± 1.86	0.00 ± 0.00	1.25	0.26
2004	2.33 ± 2.33	8.67 ± 5.70	3.09	0.08
2005	1.00 ± 0.58	1.67 ± 0.88	0.10	0.76

Table 6.4. Comparisons on mean number of *Schizocosa humilis* at Alexander State Forest between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	1.00 ± 0.58	0.33	0.56
2003	4.67 ± 4.67	2.33 ± 2.33	0.61	0.44
2004	1.67 ± 1.67	0.33 ± 0.33	0.44	0.50
2005	2.00 ± 1.53	3.00 ± 3.00	0.14	0.71

Table 6.5. Lycosidae species collected at Alexander State Forest (Trt = Treated and UnT = Untreated-control).

Species	2002 Trt	2002 UnT	2003 Trt	2003 UnT	2004 Trt	2004 UnT	2005 Trt	2005 UnT
Hogna sp. A Simon[1]	0	0	0	0	0	0	0	3
Pirata davisi Wallace and Exline[2]	0	0	0	0	0	0	1	0
Pirata hiteorum Wallace and Exline[2]	2	5	0	7	26	7	6	3
Pirata minutus Emerton[2]	0	0	0	4	0	8	0	1
Pirata sp. A Sundevall[2]	0	0	0	1	0	1	0	0
Rabidosa punctulata (Hentz)[3]	0	0	2	0	0	0	0	0
Schizocosa avida (Walckenaer)[4]	1	1	0	0	0	0	0	0
Schizocosa crassipes (Walckenaer)[4]	0	0	0	0	0	3	0	3
Schizocosa saltatrix (Hentz)[4]	1	1	0	1	0	1	0	2
Schizocosa sp. A Chamberlain[5]	0	0	0	0	0	0	0	2
Schizocosa sp. B Chamberlain[5]	1	0	1	0	0	0	0	0
Trochosa acompa (Chamberlain) [6]	1	0	1	0	0	0	0	0

Authors of keys used to identify Lycosidae: [1]Dondale and Redner 1990 (Note some *Hogna* species are currently classified as *Lycosa* and *Rabidosa*); [2]Wallace and Exline 1978; [3]Brady and Mckinely 1994; [4]Dondale and Redner 1978; [5]Stratton 1991, [6]Brady 1980.

Table 6.5. Continued.

Species	2002 Trt	2002 UnT	2003 Trt	2003 UnT	2004 Trt	2004 UnT	2005 Trt	2005 UnT
Trabeops aurantiacus (Emerton) [7]	0	0	0	1	0	0	2	2
Varacosa avara (Keyserling)[7]	0	0	0	0	0	0	3	0

Authors: [7]Dondale and Redner 1990.

Sandy Hollow WMA

At Sandy Hollow WMA 161 adult Lycosidae were collected throughout the study. During period A, no significant difference was found in mean number of individuals between untreated-control (3.33 ± 1.33) and treated plots (6.00 ± 0.58) at the family level ($\chi^2_1 = 0.76$, P = 0.38). Additionally, no significant difference in mean number of individuals, in family Lycosidae, was detected in 2003, 2004, and 2005 between untreated-control plots (5.67 ± 3.18, 3.00 ± 0.58, and 16.00 ± 7.23, respectively) compared with treated plots (6.67 ± 2.91, 4.67 ± 1.45, and 8.00 ± 3.06; $\chi^2_1 = 0.08$, P = 0.77, $\chi^2_1 = 0.36$, P = 0.55, and $\chi^2_1 = 2.67$, P = 0.10, respectively).

Immature Lycosidae at Sandy Hollow WMA consisted of 143 collected individuals. During period A, no significant difference was found in mean number of immature Lycosidae between untreated-control (8.33 ± 0.67) and treated plots (10.67 ± 0.88, $\chi^2_1 = 0.29$, P = 0.59). Additionally in 2003, 2004, and 2005, no significant difference in mean number of immatures was detected between untreated-control plots (4.33 ± 2.03, 4.67 ± 1.20, and 5.33 ± 0.67, respectively) compared with treated plots (5.00 ± 2.52, 5.33 ± 2.03, and 4.00 ± 1.53; $\chi^2_1 = 0.05$, P = 0.83, $\chi^2_1 = 0.04$, P = 0.83, and $\chi^2_1 = 0.19$, P = 0.66, respectively).

Sixty-nine individuals from genus *Pardosa* and 70 individuals from genus *Pirata* were collected throughout the study, representing 86% of all Lycosidae collected. Mean number of individuals from genus *Pardosa* were found to be significantly higher on untreated-control plots (9.00 ± 4.36) compared with treated plots (0.67 ± 0.33) in 2005 ($\chi^2_1 = 7.18$, P = 0.007). *Pardosa* were not found to differ significantly in Period A, 2003, and 2004 between untreated-control (1.67 ± 1.20, 4.67 ± 3.18, and 1.67 ± 0.88, respectively) and treated plots (1.00 ± 0.58, 3.33 ± 2.85, and 1.00 ± 1.00; $\chi^2_1 = 0.17$, P = 0.68, $\chi^2_1 = 0.22$, P = 0.64, and $\chi^2_1 = 0.17$, P = 0.68). No significant difference in mean number of individuals in genus *Pirata* between untreated-control and treated plots was detected in period A, 2003, 2004, and 2005 (Table 6.6).

Table 6.6. Comparisons on mean number of *Pirata* at Sandy Hollow WMA between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.33 ± 0.33	0.33 ± 0.33	1.83	0.18
2003	0.67 ± 0.33	0.67 ± 0.33	1.48	0.22
2004	0.67 ± 0.67	0.67 ± 0.67	1.77	0.18
2005	6.33 ± 3.33	6.33 ± 2.72	0.00	1.00

One species collected from Sandy Hollow WMA, *Pirata davisi* is a new record for Louisiana. Sixty-six *Pardosa atlantica* and 38 *Pirata hiteorum* were collected at Sandy Hollow WMA. Mean number of *Pardosa atlantica* were found to be significantly higher on untreated-control plots (9.00 ± 4.36) compared with treated plots (0.67 ± 0.33) in 2005 ($\chi^2_1 = 7.18$, P = 0.007). *Pardosa atlantica* were not found to differ significantly in Period A, 2003, and 2004 between untreated-control (1.67 ± 1.20, 4.67 ± 3.18, and 1.67 ± 0.88, respectively) and treated plots (1.00 ± 0.58, 2.33 ± 2.33, and 1.00 ± 1.00; $\chi^2_1 = 0.17$, P = 0.68, $\chi^2_1 = 0.78$, P = 0.38, and $\chi^2_1 = 0.17$, P = 0.68). No significant difference in mean number of individuals in genus *Pirata hiteorum* between untreated-control and treated plots was detected in period A, 2003, 2004, and 2005 (Table 6.7). Table 6.8 shows all eighteen Lycosidae species collected at Sandy Hollow WMA.

Discussion

The biology, ecology, and abundance of Lycosidae in Louisiana are poorly known, much less the impacts that RIFA may pose on this particular taxon. Lycosidae collected from pitfalls

Table 6.7. Comparisons on mean number of *Pirata hiteorum* at Sandy Hollow WMA between untreated-control and treated plots.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	1.00 ± 0.58	0.33	0.56
2003	0.33 ± 0.33	1.33 ± 0.33	0.27	0.60
2004	0.00 ± 0.00	2.00 ± 1.15	1.00	0.31
2005	2.67 ± 1.20	5.33 ± 2.33	0.71	0.40

were identified to family (adults and immatures), genera, and species to compare with ordinal level classification (Chapter 5), in respect to impacts RIFA may pose to this taxon. At both Alexander State Forest and Sandy Hollow WMA, ordinal level classification of Araneae showed no significant difference in mean number of individuals between untreated-control plots compared with treated plots for period A, 2003, 2004, and 2005 (Chapter 5).

Similarly, at Alexander State Forest, no significant difference in mean number of individuals in family (adults and immatures), genus, and species classifications were detected between untreated-control and treated plots, for period A, 2003, 2004, and 2005. Based on results presented here, and those from Chapter 5, Lycosidae populations at Alexander State Forest may not be regulated by RIFA, and other biotic or abiotic factors are regulating these individuals. Studies conducted by Porter and Savignano (1990) and Galarraga (2003) support these results. Porter and Savignano (1990) found no significant difference in mean number of individual Araneae at both the ordinal level and species level between uninfested sites and sites infested with RIFA. Galarraga (2003) also detected no significant difference in Lycosidae at thefamily level between sites with RIFA and sites where RIFA was suppressed. Further more,

Table 6.8. Lycosidae species collected at Sandy Hollow WMA (Trt = Treated and UnT = Untreated-control).

Species	2002 Trt	2002 UnT	2003 Trt	2003 UnT	2004 Trt	2004 UnT	2005 Trt	2005 UnT
Hogna georgicola (Chamberlain and Ivie)[1]	0	0	0	0	0	0	1	0
Hogna lenta (Hentz)[1]	0	0	0	0	0	0	1	0
Hogna sp. A Simon	0	0	0	0	0	1	0	0
Hogna sp. B Simon[1]	0	1	0	0	1	0	1	0
Pardosa atlantica Emerton[2]	3	5	7	14	3	5	2	27
Pardosa milvina (Hentz)[3]	0	0	2	0	0	0	0	0
Pirata alachuus Gretsch and Wallace[4]	0	0	3	0	0	0	1	1
Pirata apalacheus Gretsch[5]	1	1	1	0	2	2	1	2
Pirata davisi Wallace and Exline	1	0	0	0	1	0	0	0
Pirata hiteorum Wallace and Exline	3	0	4	1	6	0	16	8
Pirata minutus Emerton	2	0	1	1	1	0	1	3
Pirata sp. A Sundevall	1	0	0	0	0	0	0	0
Rabidosa punctulata (Hentz)	1	1	0	0	0	0	0	0

Authors: [1] Dondale and Redner 1990 (Note some *Hogna* species here are currently classified as *Lycosa* or *Rabidosa*); [2,3]Vogel 2004; [4,5]Wallace and Exline 1978.

Table 6.9 continued.

Species	2002 Trt	2002 UnT	2003 Trt	2003 UnT	2004 Trt	2004 UnT	2005 Trt	2005 UnT
Schizocosa avida (Walckenaer)	4	2	0	1	0	1	0	0
Schizocosa ocreata (Hentz)[6]	0	0	0	0	0	0	0	1
Schizocosa saltatrix (Hentz)	0	0	0	0	0	0	0	1
Sosipus mimus Chamberlain[7]	1	0	1	0	0	0	0	1
Varacosa avara (Keyserling)	1	0	0	0	0	0	0	0

[6] Dondale and Redner 1978; [7]Brady 1962.

ecological studies centered on Lycosidae, at Alexander State Forest, may only need to focus at family level, with respect to long-term studies on RIFA-Lycosidae interactions. Family level identification of Lycosidae is fairly straight forward and produced similar results to analyses of genus and species level classification at Alexander State Forest.

Family level identifications (adults and immatures) of Lycosidae at Sandy Hollow WMA found no significant difference in mean number of individuals between untreated-control and treated plots for period A, 2003, 2004, and 2005. Similarly, genus *Pirata* and species *Pirata hiteorum* showed no difference in mean number of individuals between untreated-control and treated plots in period A, 2003, 2004, and 2005. However, both genus (*Pardosa*) and species (*Pardosa atlantica*) classifications detected a higher mean number of individuals on untreated-control plots in 2005. Since individuals were found to be higher on untreated-control plots, RIFA may not be the regulating factor of these populations. Findings by Morrison (2002), conducted at the same sites as Porter and Savignano (1990), showed that spiders classified at the ordinal level and species level significantly increased in the presence of RIFA in a span of 12 years. Due to the early successional nature of Sandy Hollow WMA and abundance of micro-habitats, formed by successional gradients, Lycosidae and RIFA may not exhibit significant predator-prey interactions, which would regulate Lycosidae populations. As opposed to ecological studies conducted at Alexander State Forest, similar results between analyses of family, genus, and species level classification were not shown. In certain habitat types, such as Sandy Hollow WMA, species level determinations of Lycosidae, rather than family or genus level classification, may be more useful in studying the impacts RIFA pose on Lycosidae populations.

Pirata davisi collected at both Alexander State Forest and Sandy Hollow WMA, and *Trabeops aurantiacus* collected at Alexander State Forest are new state records (Anonymous

2001, Platnick 2005). No biological information is presently available for *P. davisi*, it has only been collected from Mexico and Texas. Two specimens of *P. davisi* were collected from Sandy Hollow WMA and one from Alexander State Forest. In Louisiana, this species exists in both dense pine-hardwood habitats and grassy savanna habitats, and thus adapted to both wet and dry habitat conditions. *Trabeops aurantiacus* is widespread across the United States, yet little biological information is available for this species too. Five individuals were collected from Alexander State Forest, yet none were collected from Sandy Hollow WMA. In Louisiana, *Trabeops aurantiacus* occurs in the United States as far west as Montana, as far east as New York, and as far south as Mississippi (Anonymous 2001). However, in Louisiana it has only been collected from Alexander State Forest which may signify a preference for moist habitat types.

Based on these results, RIFA may not regulate Lycosidae populations, however further research should be conducted on impacts RIFA may pose to other families and species of spiders. Furthermore, spider species and, in particular, Lycosidae species in Louisiana are poorly known and deserve further research.

Chapter 7.

Impacts of Red Imported Fire Ants on Non-Target Ant Communities in Longleaf-pine and Pine-hardwood Forests

Introduction

Since its introduction, it appears polygynous RIFA have been able to competitively replace many species of native ants (Porter and Savignano 1990). Once established, RIFA persist and dominate the habitat, becoming a keystone species and influencing community structure (Wojcik 1994). RIFA may have displaced two native species of *Solenopsis* (*S. geminata* and *S. xyloni*) throughout most of their range, and RIFA has confined the invasive black imported fire ant (*S. richteri*) to northern parts of its range in Mississippi and Alabama (Vinson 1994, Vinson 1997). Camilo and Philips (1990) report that within the range of RIFA, diversity of other ant assemblages are negatively affected by the large densities that RIFA attain and that granivorous ant species in genus *Pheidole* (*P. tepicana* Pergande and *P. crassicornis tetra* Creighton) are replaced faster than other ant species. Nichols and Sites (1991) confirmed these results, documenting the diversity of the ant community was less within range of RIFA than outside the range. However, they also recorded 12 new species of ants that actively prey upon RIFA founder queens (Nichols and Sites 1991).

Jusino-Atresino and Phillips (1994) conducted a study in Taylor County, Texas, comparing a study site infested with RIFA to another that RIFA had not yet invaded. They found seventeen species of ants, collected from pitfalls, common to both sites (Jusino-Atresino and Phillips 1994). Only six of the seventeen species were collected in higher numbers in the infested site, while the other eleven species were found in higher abundance at the uninfested site (Jusino-Atresino and Phillips 1994). Most species were adversely affected by RIFA with a reduction in excess of 20% in number of individuals (Jusino-Atresino and Phillips 1994). The little black ant

(*Monomorium minimum* Buckley) was most affected with a reduction of 76% in number of individuals collected between infested and uninfested sites (Jusino-Atresino and Phillips 1994).

Another study with similar results was conducted by Cook (2003); he compared number of individuals of non-RIFA species in a previously infested field site with one that was managed for RIFA with bait treatments. Both plots had essentially the same species at the start of the study (Cook 2003). He found the loss of four species *Monomorium minimum*, two species of *Pheidole*, and *Pogonomyrmex barbatus* (Smith) within the recently RIFA infested site, but the addition of one *Cyphomyrmex* species to the treated/managed site (Cook 2003).

Porter and Savignano (1990) found that species richness in areas infested with RIFA was 70% lower than before infestation and that the total number of native individuals dropped by 90% compared with uninfested sites. However, Morrison (2002) reconstructed this same experiment in 1999 using Porter and Savignano's (1990) same experimental design and obtained very different results. He found that overall abundance of RIFA was reduced from 99.6% of species present in pitfalls and 94.5% of species present in bait traps in 1990 to ~33% of the species present in pitfalls and ~40% of species present at baits in 1999 (Porter and Savaginano 1990, Morrison 2002). Morrison (2002) did not conclude that negative effects of RIFA will disappear with time, but that the greatest impacts seem to occur during and shortly after the initial invasion.

Non-target ant species from ant vials were used to assess the impacts RIFA pose on other species of ants at Alexander State Forest and Sandy Hollow WMA. Observations were made on negative effects of Amdro® on non-target ant species, as well as possible cases of competitive release of non-target ant species in response to treatment, coexistence between RIFA and non-target ant species, and non-target ant species whose populations fluctuate but may not be responding to RIFA suppression.

Methods

Ant Sampling

Refer to Chapter 2 methods: Red Imported Fire Ant Control and Ant Sampling. Non-target ant species were identified by Shawn T. Dash.

Statistical Analysis

SAS version 9.1 software package was used to assess impacts RIFA pose on non-target ant communities in two pine-dominated ecosystems in Louisiana (SAS Institute Inc. 2002). Chi-square analyses were used to test for significant differences in mean number of non-target ant species. Analyses were conducted between untreated-control and treated plots for period A, 2003, 2004, and 2005. Due select times certain species were collected and low sample sizes only certain species could be appropriately analyzed. At Alexander State Forest both *Aphaenogaster rudis-texana* (Umphrey), *Brachymyrmex musculus* Forel, *Crematogaster lineolata* (Say), *Monomorium minimum*, *Paratrechina faisonensis* (Forel), *Pheidole dentata* Mayr, and *Tapinoma sessile* (Say) were collected with sufficient numbers to analyze. At Sandy Hollow WMA *Brachymyrmex musculus*, *Dorymyrmex bureni* Buckley, *Monomorium minimum*, *Paratrechina faisonensis*, *Pheidole dentata*, *Pheidole metallescens* Emery, and *Prenolepis imparis* (Say) were analyzed. Statistical significance was determined at $\alpha = 0.05$.

Results

Of the eight species analyzed, two species showed a positive response to treatment: *Brachymyrmex musculus* and *Tapinoma sessile* (Tables 7.1 and 7.2). Both *Monomorium minimum* and *Paratrechina faisonensis* did not respond positively to treatment, but appear to coexist with RIFA on untreated-control and treated plots (Tables 7.3 and 7.4). The last three species analyzed, *Aphaenogaster rudis-texana*, *Crematogaster lineolata*, and *Pheidole dentata* did not respond to RIFA suppression, but showed population fluctuations that may not be regulated by RIFA (Tables 7.5, 7.6, and 7.7). Table 7.8 shows all sixteen non-target ant species collected at Alexander State Forest; the table lists total number of individuals collected on untreated-control and treated plots for each sampling year.

Table 7.1. Comparisons on mean number of *Brachymyrmex musculus* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00
2003	0.00 ± 0.00	117.67 ± 117.67	115.70	< 0.0001
2004	0.00 ± 0.00	15.33 ± 15.33	13.56	0.0002
2005	0.00 ± 0.00	22.33 ± 22.33	19.50	< 0.0001

Table 7.2. Comparisons on mean number of *Tapinoma sessile* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00
2003	0.00 ± 0.00	175.33 ± 175.33	173.35	< 0.0001
2004	59.33 ± 58.83	738.00 ± 738.00	576.22	< 0.0001
2005	0.00 ± 0.00	68.33 ± 48.86	66.39	< 0.0001

Table 7.3. Comparisons on mean number of *Monomorium minimum* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	281.00 ± 202.89	5.33 ± 5.33	263.57	< 0.0001
2003	211.00 ± 159.63	6.67 ± 6.67	190.06	< 0.0001
2004	30.00 ± 29.00	28.67 ± 28.67	0.02	0.86
2005	39.00 ± 39.00	0.00 ± 0.00	37.10	< 0.0001

Table 7.4. Comparisons on mean number of *Paratrechina faisonensis* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	108.67 ± 108.67	70.33 ± 60.84	8.21	0.04
2003	20.00 ± 11.85	4.33 ± 3.38	10.09	0.002
2004	170.00 ± 79.25	21.00 ± 19.04	116.24	< 0.0001
2005	247.00 ± 214.71	130.67 ± 107.17	35.83	< 0.0001

Table 7.5. Comparisons on mean number of *Aphaenogaster rudis-texana* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	10.33 ± 10.33	0.00 ± 0.00	8.65	0.003
2003	20.67 ± 20.67	0.00 ± 0.00	18.85	< 0.0001
2004	1.67 ± 1.67	0.00 ± 0.00	0.76	0.38
2005	0.00 ± 0.00	0.00 ± 0.00	0	1.00

Table 7.6. Comparisons on mean number of *Crematogaster lineolata* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	73.67 ± 73.67	21.33 ± 21.33	28.24	< 0.0001
2003	25.00 ± 25.00	3.00 ± 3.00	16.13	< 0.0001
2004	0.00 ± 0.00	52.00 ± 52.00	50.07	< 0.0001
2005	0.00 ± 0.00	0.67 ± 0.67	0.17	0.68

Table 7.7. Comparisons on mean number of *Pheidole dentata* from ant vials at Alexander State Forest for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	1.33 ± 1.33	58.00 ± 58.00	52.36	< 0.0001
2003	0.00 ± 0.00	1.67 ± 1.67	0.76	0.38
2004	4.00 ± 4.00	1.33 ± 0.88	0.97	0.32
2005	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00

Of the seven species analyzed at Sandy Hollow WMA, four (*Brachymyrmex musculus*, *Paratrechina faisonensis*, *Pheidole dentata*, and *Pheidole metallescens*) did not respond to RIFA suppression, but showed population fluctuations that may not be regulated by RIFA (Tables 7.9, 7.10, 7.11, and 7.12). *Dorymyrmex bureni* did not respond positively to treatment and seemed to coexist with RIFA on untreated-control and treated plots (Table 7.13). *Monomorium minimum* were not caught on untreated-control plots throughout the study, but responded negatively toward Amdro® treatments (Table 7.14).*Prenolepis imparis* also exhibited a negative response to Amdro® treatments (Table 7.15). Table 7.16 shows all thirteen non-target ant species

Table 7.8. Number of individuals of non-target ant species at Alexander State Forest for untreated-control and treated plots for each sampling year.

Species	2002 Treated	2002 Untreated-Control	2003 Treated	2003 Untreated-Control	2004 Treated	2004 Untreated-Control	2005 Treated	2005 Untreated-control
Aphaenogaster rudis-texana	0	62	0	31	0	5	0	0
Brachymyrmex musculus	0	0	353	0	46	0	76	0
Creamatogaster ashmeadi Emery	0	0	0	160	0	0	0	0
Creamatogastor lineolata	64	221	81	75	156	0	2	0
Creamatogaster pilosa Emery	20	62	0	99	0	0	0	0
Dorymyrmex bureni	0	0	20	0	0	0	0	0
Monomorium minimum	182	843	20	633	86	90	0	117
Paratrechina arenivaga (Wheeler)	0	0	0	15	0	135	0	0
Paratrechina faisonensis	211	326	13	60	63	510	392	742
Pheidole dentata	174	4	5	0	4	12	0	0
Pheidole metalescens	0	38	0	0	0	0	0	0
Pheidole soritis Wheeler	0	0	0	0	0	0	0	16
Pheidole tysoni Forel	0	63	0	0	0	0	0	0

Table 7.8. Continued.

Species	2002 Treated	2002 Untreated-Control	2003 Treated	2003 Untreated-Control	2004 Treated	2004 Untreated-Control	2005 Treated	2005 Untreated-control
Prenolepis imparis	0	55	0	41	0	0	0	0
Solenopsis molesta (Say)	0	0	0	161	0	0	0	0
Tapinoma sessile	0	0	526	0	2214	178	205	0

at Sandy Hollow WMA; the table lists total number of individuals collected on untreated-control and treated plots for each sampling year.

Table 7.9. Comparisons on mean number of *Brachymyrmex musculus* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	18.67 ± 18.67	16.86	< 0.0001
2003	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00
2004	0.67 ± 0.67	114.67 ± 109.70	110.76	< 0.0001
2005	0.00 ± 0.00	7.67 ± 7.67	6.08	0.01

Table 7.10. Comparisons on mean number of *Paratrechina faisonensis* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	1.33 ± 1.33	2.33 ± 1.45	0.18	0.67
2003	0.00 ± 0.00	11.00 ± 11.00	9.31	0.002
2004	17.33 ± 17.33	8.00 ± 4.62	3.19	0.07
2005	0.00 ± 0.00	107.33 ± 106.80	105.37	< 0.0001

Table 7.11. Comparisons on mean number of *Pheidole dentata* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00
2003	90.33 ± 45.74	63.33 ± 63.33	4.68	0.03
2004	0.00 ± 0.00	9.33 ± 9.33	7.68	0.006
2005	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00

Table 7.12. Comparisons on mean number of *Pheidole metallescens* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	7.33 ± 6.84	5.76	0.02
2003	0.00 ± 0.00	24.33 ± 24.33	22.48	< 0.0001
2004	0.33 ± 0.33	9.67 ± 9.67	7.27	0.007
2005	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00

Table 7.13. Comparisons on mean number of *Dorymyrmex bureni* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	16.67 ± 16.67	0.00 ± 0.00	14.88	0.0001
2003	193.67 ± 193.67	157.00 ± 138.91	3.62	0.06
2004	34.00 ± 33.01	1.00 ± 1.00	29.43	< 0.0001
2005	0.00 ± 0.00	2.00 ± 2.00	1.00	0.32

Table 7.14. Comparisons on mean number of *Monomorium minimum* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	0.00 ± 0.00	187.67 ± 187.67	185.69	< 0.0001
2003	0.00 ± 0.00	64.33 ± 64.33	62.39	< 0.0001
2004	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00
2005	0.00 ± 0.00	0.00 ± 0.00	0.00	1.00

Table 7.15. Comparisons on mean number of *Prenolepis imparis* from ant vials at Sandy Hollow WMA for period A, 2003, 2004, and 2005.

Year	Untreat-Control Mean ± SE	Treated Mean ± SE	χ^2	P-value
2002	10.33 ± 10.33	83.67 ± 39.22	56.03	< 0.0001
2003	0.00 ± 0.00	21.67 ± 21.67	19.84	< 0.0001
2004	0.00 ± 0.00	37.00 ± 24.01	35.10	< 0.0001
2005	14.00 ± 13.50	8.33 ± 8.33	1.32	0.25

Discussion

Impacts of RIFA on native ant fauna are poorly known, and have usually been studied (in absence of insecticide treatment) by comparing habitats with and without RIFA (Porter and Savignano 1990, Justino-Atresino and Phillips 1994, and Morrison 2002). Also, impacts RIFA pose on native ants has historically been studied in highly disturbed systems that favor RIFA, including: pastures (Justino-Atresino and Phillips 1994, Morrison and Porter 2003), along paved roads (Wojcik 1994) and wooded areas juxtaposed to grassy fields (Porter and Savignano 1990 and Morrison 2002). Forested ecosystems may provide a variety of macro- and micro-habitat features that increases niche availability and abundance, allowing non-target native and non-native ant species to coexist with RIFA. Niche partitioning may decrease instances of competition and predation between RIFA and non-target ant species.

At Alexander State Forest, *Brachymrymex musculus* and *Tapinoma sessile* showed a positive response to RIFA suppression. Diets of both of these non-target species are composed of honeydew obtained from aphids and scales, although *T. sessile* also consumes arthropods (Dash 2004). RIFA may compete with both *B. musculus* and *T. sessile* for food resources and the positive response to RIFA suppression is possibly a sign of competitive release. However,

Table 7.16. Number of individuals of non-target ant species at Sandy Hollow WMA for untreated-control and treated plots for each sampling year.

Species	2002 Treated	2002 Untreated-Control	2003 Treated	2003 Untreated-Control	2004 Treated	2004 Untreated-Control	2005 Treated	2005 Untreated-control
Brachymyrmex musculus	56	0	0	0	344	2	23	0
Camponotus pennsylvanica (DeGeer)	0	0	0	12	0	47	0	9
Crematogaster ahmeadi	1	0	75	0	0	0	0	0
Dorymyrmex bureni	0	50	471	581	3	102	6	0
Monomorium minimum	563	0	193	0	0	0	0	0
Paratrechina arenivaga	32	0	0	0	2	18	0	0
Paratrechina faisonensis	7	4	33	0	24	52	322	0
Pheidole dentata	0	0	190	271	47	162	0	0
Pheidole metallescens	25	0	44	0	29	1	0	0
Pheidole morrisi (Forel)	0	0	55	0	0	0	0	0
Pheidole soritis	0	0	0	0	0	692	273	552
Prenolepis imparis	251	31	65	0	111	0	25	42
Tapinoma sessile	0	0	258	0	0	0	0	0

increases in these two species populations with a decrease in RIFA still may not be favored. *Brachymyrmex musculus* is an exotic species which was introduced into both Louisiana and Florida, and *T. sessile* is considered a household pest through most of its range (Dash 2004).

Monomorium minimum and *Paratrechina faisonensis* showed negligible response to RIFA suppression and occurred in significant numbers on both untreated-control and treated plots at Alexander State Forest. Both species may be able to coexist with RIFA in mixed pine-hardwood habitats. Apperson et al. (1984) and Porter and Savignano (1990) also showed that *M. minimum* can coexist with RIFA, although it occurs in higher numbers in absence of RIFA.

Three species (*Aphaenogaster rudis-texana*, *Crematogaster lineolata*, and *Pheidole dentata*) at Alexander State Forest exhibited random fluctuations in mean number of individuals on untreated-control and treated plots. All three species may not be regulated by RIFA, but possibly occur in sparse populations throughout the ecosystem. RIFA impacts on *A. rudis-texana* and *C. lineolata* have never been documented. Justino-Atresino and Phillips (1994) documented *P. dentata* coexisting with RIFA, although it occurred in higher numbers in uninfested sites. Glancey et al. (1976) documented population decreases of *P. dentata* following invasion of RIFA. This decrease may be partially attributable to superior recruitment and displacement abilities of RIFA over *P. dentata* (Wojcik 1994). In Louisiana, *A. rudis-texana*, *C. lineolata*, and *P. dentata* may coexist, but maintain low population sizes in presence of RIFA, within mixed pine-hardwood forests.

At Sandy Hollow WMA, *Dorymyrmex bureni* showed negligible response to RIFA suppression and maintained relatively high mean numbers of individuals on untreated-control and treated plots. *D. bureni* is a predatory species, which thrives in dry, sandy habitats (Dash 2004) like Sandy Hollow WMA. Impacts RIFA pose on this species have not yet been researched; however, based on results presented here *D. bureni* and RIFA can coexist in longleaf-pine ecosystems, in Louisiana.

Monomorium minimum and *Prenolepis imparis* both responded negatively toward Amdro® treatment at Sandy Hollow WMA. Amdro® may exhibit non-target effects to these two species in longleaf-pine ecosystems. This finding contradicts Apperson et al. (1976) who documented *M. minimum* as being one of three most abundant species collected following RIFA suppression with Amdro®.

Brachymyrmex musculus, *Paratrechina faisonensis*, *Pheidole dentata*, and *Pheidole metallescens* at Sandy Hollow WMA exhibited random fluctuations in mean number of individuals on untreated-control and treated plots. These species may not be regulated by RIFA, but possibly occur in sparse populations throughout the ecosystem. Impacts RIFA pose on *B. musculus* and *P. faisonensis* has not yet been researched. At Sandy Hollow WMA both species can coexist with RIFA, but experience drastic population fluctuations which may not be controlled by RIFA. Both *P. dentata* and *P. metallescens* populations have been shown to decrease in the presence of RIFA (Porter and Savignano 1990, Justino-Atresino and Phillips 1994, and Wojcik 1994). At Sandy Hollow WMA, *P. dentata* and *P. metallescens* are also able to coexist with RIFA, but experience drastic population fluctuations which may or may not be controlled by RIFA.

Results presented here provide the preliminary evidence that RIFA may not impact all non-target ant species present at Alexander State Forest and Sandy Hollow WMA. Only two species (*Brachymrymex musculus* and *Tapinoma sessile*) at Alexander State Forest responded positively to RIFA suppression, indicating RIFA may pose negative impacts on these two species. The other 12 species collected from both field sites, either coexist with RIFA or experience random population fluctuations that may not be due to impacts from RIFA. Further research needs to be conducted on RIFA's impacts to non-target ant species in forested ecosystems. Forests may provide adequate niche space so negative interactions between RIFA and non-target ant species are minimal.

Chapter 8.

Conclusions

Impacts of invasive species, such as RIFA, and their alteration of the structure and function of faunal communities through competition and predation have received much attention; yet little research has examined RIFA's impacts to native faunal communities in forested ecosystems. By suppressing RIFA populations with Amdro®, in two pine dominated ecosystems in Louisiana, impacts RIFA pose on cotton mice, herpetofaunal, invertebrate, Lycosidae, and non-target ant communities were examined. Furthermore, RIFA's impacts on these faunal taxa were examined at a larger spatial (2.02 ha) and temporal scale (four years) than pervious research.

RIFA suppression, using Amdro® (A.I. 0.7% hydramethylnon), in forested ecosystems can be achieved with regular, habitat dependent, broadcast treatments, administered at dusk, at a rate of 1.68 kg/ha (1.5 lb/acre). Depending on habitat type treatments may have to be administered more frequently. Alexander State Forest treatments may only need to be administered once every seven months, while treatments at Sandy Hollow WMA, a more open habitat may need to be administered every six months. At Alexander State Forest, a homogenous mixed pine hardwood habitat, RIFA suppression was achieved in two of three treatment years (2003 and 2005). Suppression of RIFA on treated plots ranged from 42.3-99%, with significant suppression lasting three months in 2003 and as long as seven months in 2005. RIFA suppression at Sandy Hollow WMA was also achieved in two of three treatment years (2004 and 2005). RIFA data in 2003, when suppression was not achieved, indicated the photodegradation of hydramethylnon. Sandy Hollow WMA is a savanna-type habitat comprised of an open canopy, a sparse mid-story, and an early successional under-story that is managed with fire for upland birds. Based on these habitat characteristics ample sunlight is reaches the forest floor, which enhances photodegradation of hydramethylnon. In 2003 all treatments were administered before daylight; with a switch to evening treatments, which gave RIFA ample time to forage before sunlight contacted the bait, suppression was achieved in 2004 and 2005 on treated plots. At Sandy Hollow WMA RIFA suppression ranged from 48-97% with significant suppression lasting four months in 2004 and six months in 2005.

Cotton mice populations at Alexander State Forest and Sandy Hollow WMA did not respond to RIFA treatment and may benefit from similar habitat characteristics that favor RIFA. At Alexander State Forest higher mean population estimates of cotton mice were detected on untreated-control compared with treated plots for all sampling years. Analyses of cotton mice at Sandy Hollow WMA revealed higher mean population estimates of cotton mice on treated plots for the three post-treatment years. However, regression analyses revealed that cotton mice populations were positively associated with RIFA populations, which indicates that both species may be regulated by similar habitat conditions (i.e. food availability). Mean cotton mice population estimates, at both field sites, were similar estimates in the literature (Gentry et al. 1968, Layne 1974, and Shadowen 1963). Mean population estimates at Alexander State Forest on treated plots was 0.71/ha and 1.75/ha on untreated-control plots. Mean population estimates at Sandy Hollow WMA on treated plots was 2.54/ha and 1.96/ha on untreated-control plots. Longevity of cotton mice has been shown to average 1.7 months, with a maximum of five months (Layne 1974); surprisingly, five individuals throughout the study exceeded these values: four individuals from Sandy Hollow WMA survived for a year and one individual from Alexander State Forest survived a year and a half.

Capture rate of herpetofauna species at both field sites was considerably low throughout the study. However, observations from capture data indicate that RIFA may negatively impact ground skinks at Alexander State Forest and southeastern five-lined skinks at Sandy Hollow WMA. At Alexander State Forest ground skink captures on untreated-control plots decreased by 33% and increased 40% on treated plots following two years of treatment. Southeastern five-lined skinks were never captured on untreated-control plots at Sandy Hollow WMA, although following a year of RIFA suppression twelve individuals were captured on treated plots in 2004 and then another three were captured on treated plots in 2005.

At Alexander State Forest and Sandy Hollow WMA RIFA pose minimal impacts on native ground-dwelling invertebrates. During period A, 2003, and 2005, at Alexander State Forest, no significant difference in mean number of ground-dwelling arthropods was detected between untreated-control and treated plots, for the seven orders analyzed. In 2004 Orthoptera (grasshoppers and crickets) was the only order to significantly differ in mean number of individuals between untreated-control and treated plots. Mean number of Orthoptera were found to be significantly higher on untreated-control plots compared with treated plots, indicating that Orthoptera communities are not regulated by RIFA in this ecosystem. Nine orders were analyzed at Sandy Hollow WMA. Mean numbers of Acari (mites and ticks) in 2002, Hymenoptera (wasps, bees and ants, including RIFA) in 2004, and Collembola (springtails) in 2005 were all found to be significantly higher on untreated-control plots compared with treated plots, indicating that RIFA is not regulating these communities in this ecosystem. Higher mean number of Hymenoptera on untreated-control plots in 2004 coincided with the switch from morning to evening applications of Amdro® and further supports the effectiveness of evening administered treatment regimes. Coleoptera (beetles) in 2003 was the only order at Sandy Hollow to be found in significantly higher mean numbers on treated plots compared with untreated-control plots. However, this finding did not present itself again in 2004 or 2005 which indicates that RIFA may not have been the regulatory factor in Coleoptera communities either.

Interpreting ecological results where ordinal level classification is used requires some discretion, due to the wide range of life-histories species contain within orders. To alleviate some concerns, Lycosidae (wolf spiders) were identified to species, and impacts RIFA pose to the family, immatures, genera, and species were analyzed. At Alexander State Forest no significant difference in mean number of individuals within Lycosidae at the family, immature, genus, and species level was found in period A, 2003, 2004, and 2005. During period A, 2003, and 2004, at Sandy Hollow WMA, mean number of individuals within Lycosidae were not found to differ between untreated-control and treated plots. However, in 2005 mean number of individuals within genus *Pardosa* and species *Pardosa atlantica* were found to be significantly higher on untreated-control compared with treated plots. Based on these results, RIFA populations may not regulate Lycosidae populations, at any level of identification, at Alexander State Forest and Sandy Hollow WMA. Two Lycosidae species *Pirata davisi* and *Trabeops aurantiacus* were new collection records for Louisiana.

Impacts RIFA and Amdro® pose to non-target ant species were also analyzed at Alexander State Forest and Sandy Hollow WMA. At Alexander State Forest, both *Brachymrymex musculus* and *Tapinoma sessile* showed a positive response to RIFA suppression, indicating signs of competitive release. *Monomorium minimum* and *Paratrechina faisonensis* were found to coexist with RIFA, while *Aphaenogaster rudis-texana*, *Crematogaster lineolata*, and *Pheidole dentata* were found to coexist, but maintain considerably low population sizes in the presence of RIFA. At Sandy Hollow WMA *Monomorium minimum* and *Prenolepis imparis* responded negatively to treatment, indicating that Amdro® may exhibit non-target effects to these two species in this ecosystem. *Dorymrymex bureni* was found to coexist with RIFA, while *Brachymrymex musculus*, *Paratrechina faisonensis*, *Pheidole dentata*, and *Pheidole metallescens* were found to coexist, but maintain considerably low population sizes in the presence of RIFA.

Research on the landscape-scale efficacy of Amdro® at suppressing RIFA populations over a long temporal scale, within multiple habitats, and ecological impacts that RIFA pose to native faunal communities deserves further attention. Community-level sampling of RIFA, ground-dwelling invertebrates, herpetofauna, Lycosidae, and non-target ants may not have been achieved in this study; although the experimental design incorporated a larger spatial scale than previous studies. Cotton mice were likely captured at the community-level, based on published densities. However, RIFA foragers have been shown to forage 15-25 m from their colony (Lofgren et al. 1975), which would indicate that samples collected from 2.02 ha plots may not be assessing RIFA at community-levels. Published literature on community-level sampling of ground-dwelling invertebrates and Lycosidae is scarce, as well as hard to determine due to multitude of life-history strategies within these two taxa. Community-level sampling for non-target ants also depends a great deal on the focal species. In two pine-dominated ecosystems, in Louisiana, RIFA can be suppressed with regular (habitat dependent) treatments of Amdro®, which allows researchers to monitor the impacts RIFA pose on numerous faunal taxa. At Alexander State Forest and Sandy Hollow, RIFA may only pose minimal impacts to cotton mice, ground-dwelling invertebrates, species of Lycosidae, and non-target ants, and may not be the regulating factor in these communities. However, herpetofaunal communities in these two ecosystems may be negatively impacted by RIFA, although more intensive sampling for specific species will be needed to better understand the impacts that RIFA pose on these communities.

This research provides preliminary evidence on the long term, large scale impacts RIFA pose to native faunal communities, in Louisiana, in forested ecosystems.

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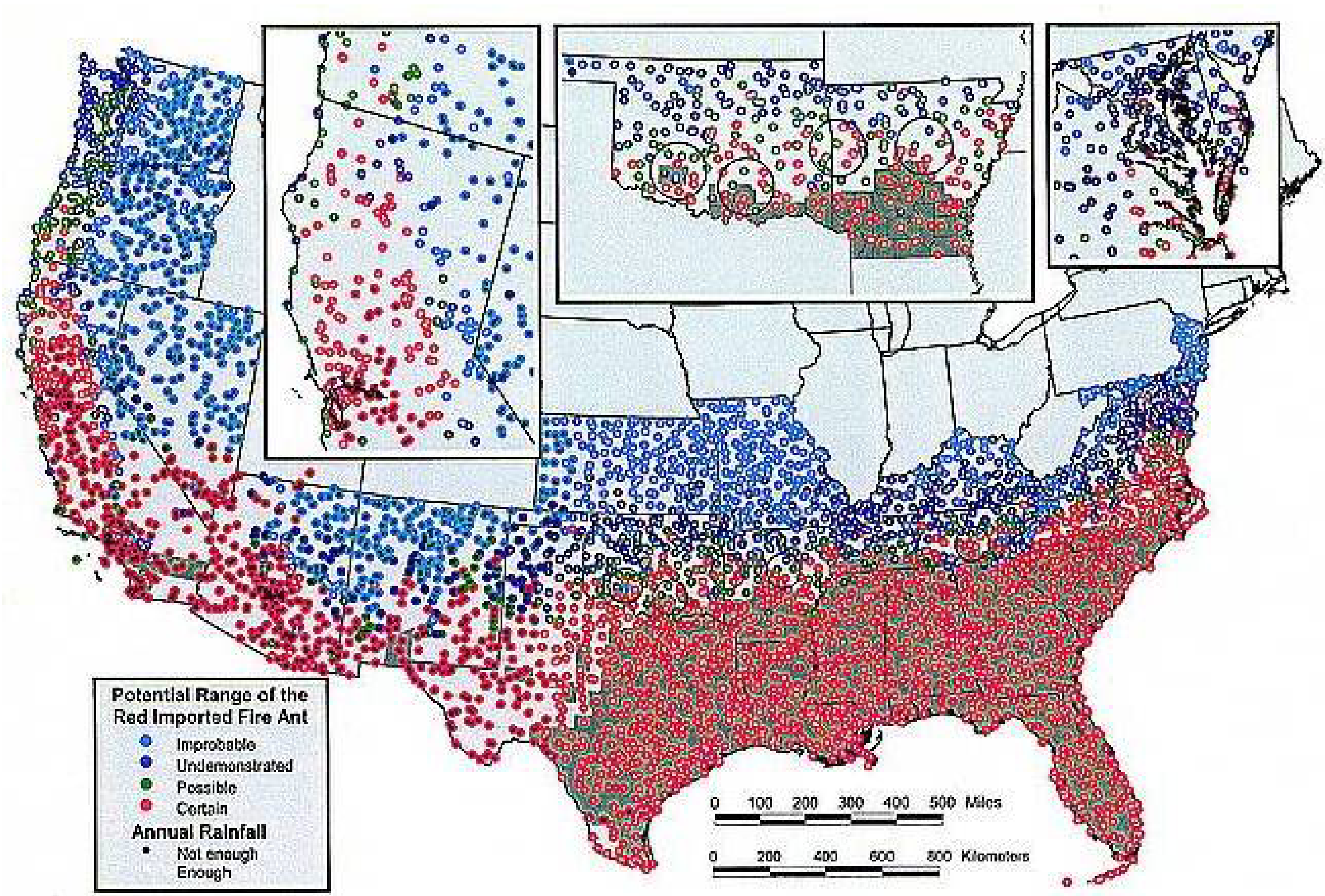
Appendix A: Red Imported Fire Ant Range Map



A detailed map of the present range and possible future of RIFA expansion in the United States, presented by Korzukhin et al. 2001.

Appendix B: Small Mammal Species Captured at Alexander State Forest and Sandy Hollow WMA

	Species Captured	Common Name	Total Captured	Percent of Total Captured
Alexander State Forest				
	Peromyscus gossypinus	Cotton Mouse	61	32.4%
	Sigmodon hispidus	Hispid Cotton Rat	54	28.7%
	Reithrodontomys fulvescens	Fulvous Harvest Mouse	25	13.3%
	Peromyscus leucopus	White-footed Mouse	24	12.8%
	Ochrotomys nuttalli	Golden Mouse	19	10.1%
	Sorex longirostris	Southeastern Shrew	5	2.7%
Sandy Hollow WMA				
	Peromyscus gossypinus	Cotton Mouse	93	67.0%
	Sigmodon hispidus	Hispid Cotton Rat	37	26.6%
	Peromyscus leucopus	White-footed Mouse	7	5.0%
	Ochrotomys nuttalli	Golden Mouse	2	1.4%

Appendix C: Ground Dwelling Invertebrate Orders Collected at Alexander State Forest

Alexander State Forest

Orders Collected	Common Name	Total Individuals Captured
Araneae	Spiders	1038
Acari	Mites and Ticks	322
Chilopoda	Centipeds	44
Diplopoda	Millipedes	13
Isopoda	Isopods	42
Archeonathid	Silverfish and Fire Brats	19
Opiliones	Daddy Long-legs	88
Collembola	Springtails	9994
Mantodea	Mantids	1
Orthoptera	Grasshoppers, Crickets and Katydids	184
Blattaria	Cockroaches	27
Trichoptera	Tricops	2
Lepidoptera	Butterflies and Moths	8
Hemiptera	Ture Bugs and Plant Hoppers	141
Coleoptera	Beetles	675
Hymenoptera	Wasps, Bees and Ants	3401
Diptera	Flies	572

Appendix D: Ground Dwelling Invertebrate Orders Collected at Sandy Hollow WMA

Sandy Hollow WMA

Orders Collected	Common Name	Total Individuals Captured
Araneae	Spiders	981
Acari	Mites and Ticks	241
Pseudoscropiones	False Scorpions	1
Chilopoda	Centipeds	44
Diplopoda	Millipedes	178
Isopoda	Isopods	5
Archeonathid	Silverfish and Fire Brats	24
Opiliones	Daddy Long-legs	2
Collembola	Springtails	7575
Mantodea	Mantids	2
Orthoptera	Grasshoppers, Crickets and Katydids	520
Blattaria	Cockroaches	22
Trichoptera	Tricops	4
Psocoptera	Psocops	1
Lepidoptera	Butterflies and Moths	6
Hemiptera	Ture Bugs and Plant Hoppers	254
Coleoptera	Beetles	1113

Orders Collected	Common Name	Total Individuals Captured
Hymenoptera	Wasps, Bees and Ants	8839
Diptera	Flies	587

Vita

Lee Womack was born July 14, 1982, in Slidell, Louisiana. He graduated from Slidell High School in spring of 2000 and immediately began his college career at Louisiana State University in Baton Rouge, Louisiana. Lee received his Bachelor of Science degree in wildlife and fisheries conservation with a minor in biology in the spring of 2004. Lee held several internship positions; including positions with the LaCombe Fish Hatchery in LaCombe, Louisiana; United States Geological Survey in Bay St. Louis, Louisiana; National Oceanic and Atmospheric Administration in Slidell, Louisiana; and Environmental Enterprises in Slidell, Louisiana. He gained experience working with threatened fish such as sturgeon, fish stocking projects for largemouth bass and stripped bass, river and bayou flood stage monitoring and mapping, as well as aquaculture research. Upon graduating with his bachelor's degree, he was accepted into graduate school under the direction of Drs. Linda Hooper-Bui and Michael Chamberlain. Lee will be awarded a Master of Science degree in wildlife with a minor in entomology in May 2006.